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Editor's Page

Uniting to fight COVID-19

The coronavirus pandemic has very quickly changed our lives in ways we could not have imagined even a few short months ago. Our vocabulary reflects some of these changes, with new terms that have become commonplace, like "social distancing" and "flattening the curve." These are unprecedented times, and the world is united in fighting a common, unseen enemy, the novel coronavirus. In this battle, we arm ourselves with soap, disinfectants and personal protective equipment (PPE). The widespread need for these materials in quantities never anticipated has caused worldwide shortages and desperate calls for help in supplying them. The chemical process industries (CPI), large and small, and the vendors that supply them are answering the calls.

Donations and production shifts

The CPI provide numerous materials needed for the COVID-19 response, including ingredients for cleaners, disinfectants and hand sanitizers, plastics used in medical equipment and materials used to make PPE. To meet the demands, many companies are cooperating with each other, and in some cases, donating raw materials to each other to produce end products. Companies are also shifting their production to include products they don't normally make.

Dow, for example, which normally does not produce hand sanitizer, began producing it at five of its sites, located in the U.S. (Michigan and West Virginia), Belgium, Brazil and Germany. The majority of the hand sanitizer produced is intended as donations to health systems and government agencies, and it will also be distributed to Dow production sites to help protect its own employees.

Huntsman started making hand sanitizer at its manufacturing site in Alabama, for distribution to health care facilities in the U.S. Since Huntsman does not make the needed isopropanol, LyondellBasell agreed to donate the alcohol to produce the first shipment. Ineos, Henkel, Arkema and numerous distilleries are among a host of companies that are also shifting production to meet hand-sanitizer and other disinfectant needs.

Providing material for PPE is another area seeing much activity in the CPI. For example, Exxon Mobil is working with the Global Center for Medical Innovation (GCMI) to facilitate the development and expedite third-party production of innovative safety equipment that can be sterilized and worn multiple times. A new industrial-style mask is being fast-tracked for production. Additional companies that are working on the response to PPE needs include Solvay, Siemens, Eastman Chemical and many others.

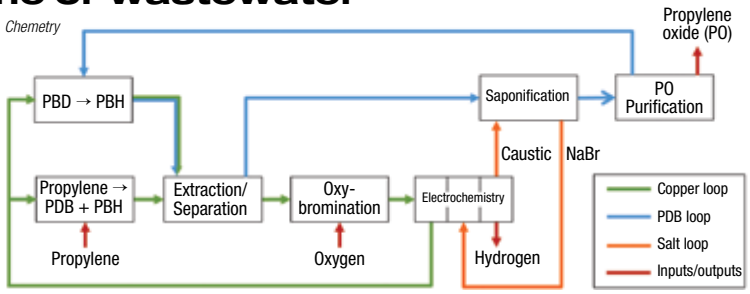
Economic impact

Last month, The American Chemistry Council (www.americanchemistry.com) released a brief update to its biannual economic report, *Chemical Industry Situation and Outlook,* to address the potential economic impact of the pandemic on the CPI. Sales in key end-use markets, such as automotive and building and construction are expected to fall sharply in 2020, but improve in 2021. The strong demand for chemical products needed for the COVID-19 response however, is expected to partially offset the weakness in U.S. chemical production. For much more on the CPI and COVID-19, as well as additional resources, see the special section on our website.* ■

Dorothy Lozowski, Editorial Director

* www.chemengonline.com/covid-19

A low-cost way to make PO without chlorine or wastewater



Chemetry Corp. (Moss Landing, Calif.; www.chemetrycorp.com) is piloting a hybrid electrochemical-catalysis process for making propylene oxide (PO) that eliminates some of the major production hurdles associated with chlorohydrin-based PO production. "The traditional chlorohydrin process produces about 47 tons of wastewater per ton of product. With our process, we are able to eliminate this wastewater stream, producing effectively nothing," says Ryan Gilliam, Chemetry CEO, also highlighting the fact that the process requires no chlorine gas and also offers a dramatic reduction in energy consumption. Chemetry's integrated pilot facility has been ramping up production in recent months, and now produces around 50 kg/d of PO. According to Gilliam, the technology is economically promising not only for existing PO producers who want to expand or retrofit their capacity, but also for locations where building a smaller-scale commercial plant is more economical than purchasing or importing PO.

Fundamentally, the closed-loop process (diagram) employs copper bromine salts, which are recycled between the electrochemical unit and the catalysis units to convert propylene and oxygen into PO. "Bromine salts offer many advantages in terms of kinetics and ease of separation," explains Gilliam. Copper bromide salts from the electrochemistry unit react with propylene in the catalysis unit, forming a split of propylene bromohydrin (PBH) and propylene dibromide (PDB). PBH, the precursor for PO production, reacts with sodium hydroxide to make PO. Simultaneously, the PDB goes into a secondary reactor where it is catalytically converted to PBH and sent to the saponification reactor. The copper is oxidized in the electrochemical cell and carries bromide back to the catalysis reactor. The closed-loop, zero-discharge nature is a cornerstone of its advantages to PO producers. "We've been able to prove that the copper stream is fully recyclable between catalysis and electrochemistry. We've been running the same copper bromide solution over the last six months in the pilot plant," adds Gilliam.

Edited by:
Gerald Ondrey

LIGHT-EMITTING Si

Researchers from Eindhoven University of Technology (TUE; the Netherlands; www.tue.nl) have developed an alloy with silicon that can emit light. Together with researchers from the universities of Jena, Linz and Munich, the researchers combined silicon and germanium in a hexagonal structure that is able to emit light — a breakthrough after 50 years of work. The findings, published in a recent issue of *Nature*, are a first step towards revolutionizing computing by making chips faster.

In contrast to electrons, photons do not experience resistance. As they have no mass or charge, they will scatter less within the material they travel through, and therefore no heat is produced. The energy consumption will therefore be reduced. Moreover, by replacing electrical communication within a chip by optical communication, the speed of on-chip and chip-

(Continues on p. 8)

An efficient electrochemical route to triphenylphosphine — without the waste

A new electrochemical process could make triphenylphosphine (TPP) — an important reagent in many organic transformations — more practical for industrial use. Synthesizing TPP results in large volumes of waste in the form of triphenylphosphine oxide (TPPO), which is very energy-intensive to handle. Now, a study led by Christo Sevov, professor of chemistry at The Ohio State University (Columbus, Ohio; www.osu.edu), has demonstrated the efficient conversion of TPPO into TPP. "In industry, people avoid these very simple and reliable reactions with TPP because of the TPPO problem. They have to come up with really circuitous routes to get to the same products that they could access in a single step if they had TPP in greater abundance, or were able to do something with the waste," explains Sevov. Currently, there is only one large-scale industrial process for recycling TPPO into TPP, and it requires massive energy input, multiple synthetic steps and the use of toxic substances like phosgene.

Beginning with an electrified aluminum container acting as the anode in an electrochemical cell, the aluminum ions are strategically stripped from the anode surface and then utilized as a Lewis-acid activator for the TPPO. "Everything is self-contained, and because you are using the waste of the anode to activate the substrate, you don't have to add any super-stoichiometric quantities of reagents, and you continuously generate the activator as you perform the electrochemical reaction," adds Sevov. This continuous generation is key, since this type of reaction normally stalls out after about only 5% completion, shutting down either because the anode is passivated or the selectivity is low.

The team has demonstrated this conversion using various aluminum sources — including soda cans and aluminum mesh fencing. This process could also unlock other organic reactions that are not industrially practical. "We are also looking at hetero-arenes and pyridines. If we can activate these with in-situ-generated Lewis acids, then we can begin doing functionalization reactions on these desirable pharmaceutical platforms," adds Sevov.

to-chip communication can be increased by a factor of 1,000, according to TUE.

To use light in chips, an integrated laser is required. The main semiconductor material that computer chips are made of is silicon. But bulk silicon is extremely inefficient at emitting light, and so was long thought to play no role in photonics. Thus, scientists turned to more complex semiconductors, such as gallium arsenide and indium phosphide. These are good at emitting light but are more expensive than silicon and are hard to integrate into existing silicon microchips. The team will now start creating a silicon laser to be integrated into current chips, which could be realized in 2020.

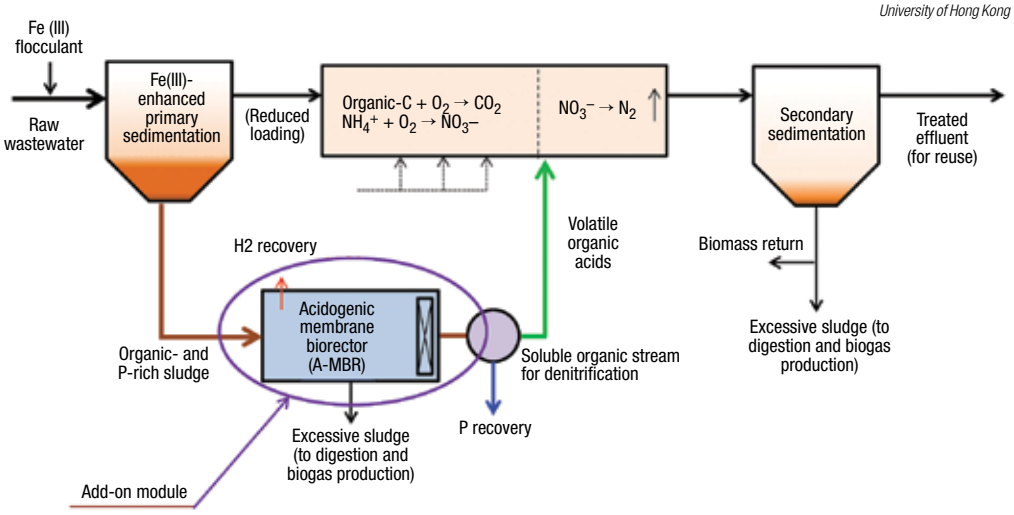
WHITE SANS TiO_2

Titanium dioxide has been the standard pigment used for white coloring of lacquers, paints, and plastics, as well as of cosmetics, foods, chewing gum and pills. "Titanium dioxide has a very high refractive index, it reflects incident light almost completely," explains professor Hendrik Hölscher of the Institute of Microstructure Technology (IMT) at the Karlsruhe Institute of Technology (KIT; Germany; www.kit.edu). "But it is associated with the drawback that its particles do not degrade and thus pollute the environment in the long term," says Hölscher.

(Continues on p. 9)

Piloting a new sewage-treatment process to tackle emerging contaminants

University of Hong Kong



As new types of water contaminants continue to emerge, such as retinoids and endocrine-disrupting chemicals, wastewater-treatment techniques are evolving to economically handle them. One new process that has shown process against both conventional and emerging water pollutants integrates two technologies in tandem — chemically enhanced primary sedimentation (CEPS) of sewage and acidogenic fermentation (AF) of sludge. The process, developed by researchers at University of Hong Kong (HKU; www.hku.hk), is being scaled up at a pilot plant in Shenzhen, China, in collaboration with the Nanshan Sewage Treatment Plant. The pilot plant is currently under construction, and is anticipated to start operations and testing within the next few months. In addition to effective removal of pollutants, the combination of CEPS and AF provides cost benefits in that it enables the recovery of salable materials, including phosphorus and organic compounds.

The CEPS portion of the process utilizes an iron flocculant fed alongside raw wastewater. The resulting sludge sidestream is then fed to an acidogenic membrane bioreactor module for organic hydrolysis (as opposed to digestion, as in a conventional sewage-treatment process). Here, a phosphorus product is recovered, and volatile organic acids are extracted back into the process. In laboratory tests comparing the new process to typical sewage-treatment processes, the combination CEPS-AF system generates cleaner effluent — the team reported that 65–80% of retinoids were removed during the CEPS step, with an additional 50% reduction following the AF step, compared to just 57% reduction using traditional treatment methods. The pilot plant will demonstrate the technology's potential to be retrofitted into existing treatment plants as an add-on module to further enhance the removal of both conventional and emerging pollutants.

First industrial-scale plant uses CO_2-lean cement production

By replacing part of cement clinker with calcined (thermally activated) clay, CO_2 emissions in cement production are lowered by up to 40%, according to thyssenkrupp Industrial Solutions AG (Essen, Germany; www.thyssenkrupp-industrial-solutions.com), which developed the technology known as "polysius activated clay." Cimpor Global Holdings B.V. (Amsterdam, the Netherlands) will use the technology on an industrial scale at a new plant being built near the Cameroon sea port of Kribi. Upon completion in fall 2021, the plant will save more than 120,000 ton/yr of CO_2 emissions. Thyssenkrupp is carrying out engineering, procurement, construction and commissioning of the new plant, which will produce 720 tons of activated clay per day. It is the second calcined clay project of Cimpor Global Holdings.

Carbon dioxide is a natural constituent of limestone, the main component of cement. For each ton of cement clinker produced, around 790 kg of process-related CO_2 is emitted. Around two thirds of this results from the limestone used, which releases CO_2 in a chemical reaction in the production process. At the same time, the process requires large amounts of energy, because for the production of cement clinker, limestone has to be heated with other aggregates to temperatures of more than 1,400°C.

With polysius activated clay, thyssenkrupp has developed a technology that allows around one third of the cement clinker to be replaced with activated clay. The clay is heated to around 800°C, which is significantly less heat than is needed to produce clinker. Thanks to the significant energy savings in the production of thermally activated clays and the changed chemical composition, CO_2 emissions per ton of cement can be cut by up to 40%, says the company.

Ion-exchange beads for lithium extraction

With lithium demand higher than ever, processors are increasingly turning toward emerging technologies and new resources for lithium extraction. A new California-based project launched by Controlled Thermal Resources (CTR; Imperial, Calif.; www.cthermal.com) and Lilac Solutions (Oakland, Calif.; www.lilacsolutions.com) aims to directly extract lithium from geothermal brines that are 4,000 ft below the surface in the Salton Sea Geothermal Field using new ion-exchange (IX) beads. "Direct lithium extraction from geothermal brines is a continuous, closed-loop process that returns spent brine to its original source. It has a very small physical footprint, is not weather-dependent and is powered by renewable energy," explains CTR principal engineer Jason Czapla.

Adapted from coating techniques used in cathode materials, Lilac Solutions' IX beads incorporate surface nano-coatings and tailored compositions to selectively absorb Li^+ ions from the brine, explains Lilac Solutions CEO Dave Snydacker. The Li^+ is then released by the addition of acid. "The beads' unique crystal structure features a very strong binding energy for lithium, enabling high recovery from lower-grade brines," adds Snydacker. Lilac has demonstrated the IX technology in two 1,000-L/h modules on brines including high concentrations of Ca^{+2} and Li^+ concentrations as low as 100 mg/L. Furthermore, the beads' surface coatings are designed to prevent degradation and enable a long lifecycle.

The modular nature of Lilac's IX technology makes it a good candidate for commercial scaleup — the team has successfully scaled from 1 L/h up to 1,000 L/h over the last 18 months. With startup anticipated later this year, the 1,000-L/h pilot plant with CTR, in concert with Lawrence Berkeley National Laboratory, San Diego State University and Nalco Water, will demonstrate brine pre-treatment alongside Lilac's IX process to produce high-purity lithium chloride, which will be further processed into lithium hydroxide and lithium carbonate at offsite facilities. CTR was recently awarded a $1.5-million grant from the California Energy Commission to put toward this piloting effort.

In addition, there have been concerns that TiO_2 could be harmful to health.

To eliminate the use of TiO_2, the researchers have developed porous polymer structures of comparably high scattering efficiency. The polymer was inspired by the white beetle *Cyphochilus insulanus*, whose chitin scales appear white thanks to their special nanostructure. "Based on this model, we produce polymer-based solid, porous nanostructures, which resemble a sponge," says Hölscher. Similar to the bubbles of shaving or bathing foam, the structure scatters light, which makes the material appear white.

"The polymer foils produced by our process are extremely thin, flexible and of low weight, but are still mechanically stable and can be applied industrially to a variety of products," the physicist explains. At a thickness of 9 µm, the polymer foil reflects more than 57% of the

(Continues on p. 10)

incident light. Increasing the thickness of the foil extends the reflectance to 80 to 90%. The sponge-like microstructure was applied to acryl glass, but the process may be transferred to many other polymers, says KIT.

CO_2 CAPTURE

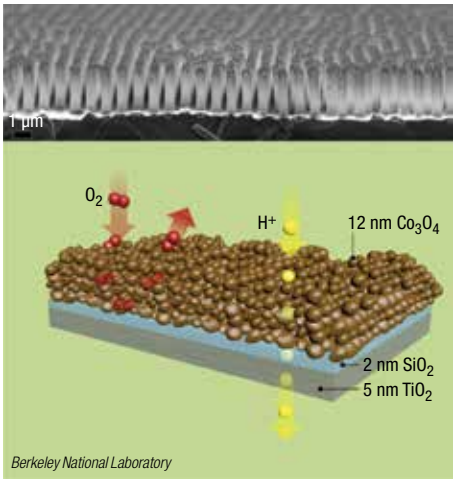
At the end of March, Calix Ltd. (Pymble, New South Wales, Australia; www.calix.global) announced final project agreements were made for the scaleup of its Low Emissions Intensity Lime And Cement (LEILAC) technology for capturing unavoidable CO_2 process emissions during the production of lime and cement. The LEILAC-2 demonstration plant will be a four-fold scaleup of the LEILAC-1 pilot plant, currently undergoing operational testing at HeidelbergCement AG's (Germany; www.heidelbergcement.com) Lixhe cement production facility in Belgium. Early results from the pilot have proven the technology concept, and work continues on the gradual increase in operational throughputs, temperatures and durability testing in a test program that will run until the end of 2020.

Officially launched on April 7, LEILAC-2 will run to the end of 2024. It will involve the design, construction and operational testing of a 100,000 ton/yr CO_2-capture facility at a working cement plant in Europe. The LEILAC-2 consortium consists of industrial partners HeidelbergCement, Cimpor, Engie, IKN and Lhoist, as well as universities, research institutes and various statutory organizations, and will be led by Calix, co-ordinated through its Calix-Europe subsidiary in France. The LEILAC 2 project is based on Calix's calcination technology and is supported with €16 million from the E.U. research funding program Horizon 2020.

More CO_2 is emitted from cement production than any other industry. Many countries, regions, and companies are now pledging net-zero CO_2 emissions by 2050. In May 2019, HeidelbergCement also committed to net zero CO_2 emissions by 2050, the first cement company to do so. ❐

'Artificial photosynthesis' system design overcomes problem of fast proton flow

Artificial photosynthesis systems seek to harvest sunlight and carbon dioxide to make fuels. Among the many challenges for making solar fuels has been achieving a fast flow of protons from where they are generated to where they combine with CO_2 and electrons to make fuel. Now, scientists at Lawrence Berkeley National Laboratory (Berkeley, Calif.; www.lbl.gov) led by Heinz Frei have demonstrated the rapid transfer of electrons in a design for "solar fuel tiles" that could allow the efficient generation of fuels from sunlight.



Berkeley National Laboratory

A recent paper from Frei's group in *Advanced Functional Materials* describes how the solar fuel tiles — which contain billions of hollow, nanoscale tubes — are able to facilitate proton transfer. The hollow tubes consist of three layers: an inner layer of cobalt oxide, where energy from sunlight is harnessed to split water molecules into protons and oxygen; and an outer layer of titanium dioxide, which supports a catalyst to promote the reaction of CO_2 into fuel. Between them, a thin layer of amorphous silica allows linkages between the two nanolayers, which provides "fast proton hopping pathways across the solid-to-solid interfaces," Frei says.

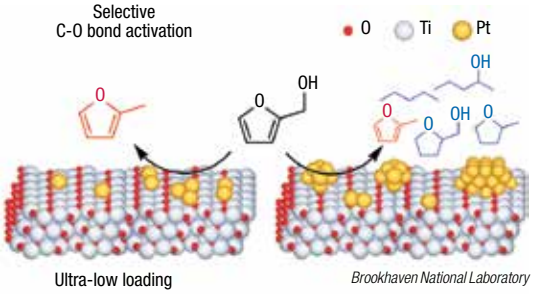
While allowing fast proton transfer, the silica layer separates the two chemical reaction zones. "This design mimics actual living photosynthetic cells, which separate oxidation and reduction reactions with organic membrane compartments inside the chloroplast," the Berkeley Lab researchers say. "Similarly in line with nature's original blueprint, the team's membrane tubes allow the photosynthetic reaction to occur over a very short distance, minimizing the energy loss that occurs as ions travel and prevent unintended chemical reactions that would also lower the system's efficiency."

Right now, CO is generated in the sunlight reaction, but the researchers are currently working toward producing methanol with the membrane.

New catalyst selectively promotes hydrodeoxygenation reaction

Scientists at Brookhaven National Laboratory (BNL; Upton, N.Y.; www.bnl.gov) and the University of Delaware (Newark; www.udel.edu) have designed a catalyst capable of selectively removing oxygen atoms from the side chain of an aromatic compound without affecting the ring. The team demonstrated the catalyst by converting the plant derivative furfuryl alcohol into the potential biofuel 2-methylfuran through a hydrodeoxygenation reaction.

The catalyst consists of highly dispersed platinum atoms (single atoms or sub-nanometer clusters) doped onto the surface of a support, the moderately reducible metal oxide TiO_2. TiO_2 was chosen because it avoids bulk reduction, which is observed with other metal oxides that are the most active for C-O bond breaking. The catalyst design selectively breaks the carbon-oxygen bond on the side group of the plant alcohol without sparking any reactions involving the aromatic ring (diagram).



Brookhaven National Laboratory

When only a low concentration of Pt is used, the ring reactions are negligible, but as the Pt concentration is increased, the platinum atoms begin to aggregate into larger clusters, which incite ring reactions, the team says.

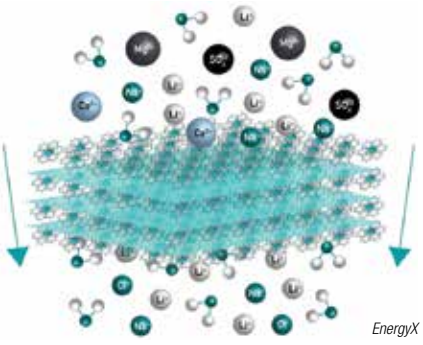
The BNL-Delaware study of biomass conversion to biofuels used a combination of experiments, characterization techniques and computer simulations that allowed a detailed understanding of the surface chemistry. This approach could help predict additional catalyst designs that could carry out other conversions of desired products, the scientists say.

MOFs and nanochannels enable lithium extraction from brines

Lithium is a key raw material for batteries that power electric vehicles, portable electronics and more, but traditional methods for obtaining it are plagued by poor lithium recovery (a large portion of Li is lost in the recovery process), slow speed (thermal evaporation of large brine ponds takes months) and poor selectivity (co-precipitation of magnesium makes isolation difficult).

Now, development is progressing on a technology that uses metal-organic frameworks (MOFs) embedded inside nanoscale channels in a polymer membrane to selectively separate lithium ions from salt brines. The method is envisioned as a more environmentally friendly lithium-harvesting alternative to conventional methods, such as mining lithium-containing ores and evaporating brine ponds under the sun.

Described in a recent paper in *Nature Materials*, the technique was pioneered by a collaborative team



EnergyX

from the University of Texas (Austin), Monash University (Melbourne, Australia) and others, and is licensed for commercialization by Energy Exploration Technologies (EnergyX; Fort Lauderdale, Fla.; www.energyX.com).

EnergyX is developing a system, known as LiTAS, for separating Li from brine that scales up the membrane technique demonstrated by the research team. To make the membrane, nanoscale channels are chemically etched into a thin polymer film, such as polyethylene terephthalate (PET), and filled with UiO-66 MOFs (zirconium oxide nanocrystals). The MOFs form complexes with carboxylic acid groups on the interior surface of the PET nanochannels.

A key aspect of the assembly is an asymmetric nanochannel that allows the MOFs to be packed at the smaller end of the channel, while the larger end is open for faster ion transport, explains UT chemical engineering professor Benny Freeman, who is working with EnergyX. The result is ion-sieving action at the MOF end of the channel that is capable of selectively transporting lithium ions. The MOFs can sort ions based on their dehydrated Bohr radius, so the membrane is more permeable for Li ions than for larger ions.

Along with industrial R&D partners, EnergyX is scaling up membrane production and integrating it into a commercial-scale system. Pilot testing using real-world brines is expected to begin in the first quarter of 2021, says Teague Egan, EnergyX CEO.

LINEUP

COVID-19 Response

Ineos constructs several new sanitizer plants in Europe

April 8, 2020 — Ineos (London; www.ineos.com) has constructed and begun operations at several hand sanitizer plants around Europe in recent weeks. The most recent plant, located in Etian, France, will serve hospitals in Paris, northeastern France and Belgium. Ineos has also built similar plants in Scotland and Germany.

Firmenich significantly expands production capacity for hand sanitizers

April 8, 2020 — Firmenich (Geneva, Switzerland; www.firmenich.com) has transformed its Geneva production site to produce hand sanitizers. Following initial production of 20 metric tons (m.t.), Firmenich increased its production capacity to manufacture 100 m.t. of sanitizer for donation in the U.S. and Switzerland.

BASF begins producing hand sanitizers in Europe and the U.S.

April 8, 2020 — BASF SE (Ludwigshafen, Germany; www.basf.com) started producing hand sanitizers at several production sites in Europe. In Düsseldorf, BASF produced and donated 13,000 L, and planned to deliver an additional 23,000 L. Similar programs are underway at sites in Spain, France and Italy. In the U.S., BASF is producing hand sanitizer at a facility in Washington, N.J., which planned to produce approximately 3,500 gal of hand sanitizer to help meet demands in the region.

Perstorp converts production to hand sanitizer and surface disinfectant

April 8, 2020 — Perstorp AB (Malmö, Sweden; www.perstorp.com) started the production of 2 million L/month of hand sanitizer and surface disinfectant for the Swedish healthcare sector.

Huntsman converts sites in Alabama and Switzerland to produce hand sanitizer

April 7, 2020 — Huntsman Corp. (The Woodlands, Tex.; www.huntsman.com) began producing hand sanitizer at its manufacturing site in McIntosh, Ala. for distribution to healthcare facilities in the U.S. Additionally, at its manufacturing site in Monthey, Switzerland, Huntsman has produced approximately 50 m.t. of hand sanitizer to donate to hospitals and pharmacies.

Honeywell boosts U.S. production capabilities for face masks

April 6, 2020 — Honeywell (Charlotte, N.C.; www.honeywell.com) is adding to its face-mask production capabilities in Phoenix, Ariz. The Phoenix expansion, coupled with additional new production in Smithfield, R.I., enables Honeywell to produce more than 20 million N95 disposable masks monthly.

Henkel converts Düsseldorf plant to produce disinfectants

April 3, 2020 — Henkel AG & Co. KGaA (Düsseldorf, Germany; www.henkel.com) has converted a production facility at its Düsseldorf site to manufacture 25,000 L/wk of hand disinfectants. Henkel will donate them to surrounding hospitals and public institutions.

Eastman donates PETG film for production of face shields

April 1, 2020 — Eastman Chemical Co. (Kingsport, Tenn.; www.eastman.com) donated polyethylene terephthalate glycol (PETG) film, a copolyester commonly used for rigid medical packaging and medical devices, to produce 10,000 face shields.

Dow launches sanitizer production on three continents

March 30, 2020 — Dow (Midland, Mich.; www.dow.com) converted several manufacturing sites to produce hand sanitizer, including: Auburn, Michigan; South Charleston, West Virginia; Seneffe, Belgium; Hortolândia, Brazil; and Stade, Germany.

MOL modifies plants in Hungary, Slovakia and Croatia for sanitizer manufacture

March 25, 2020 — MOL Group (Budapest, Hungary; www.mol.hu) started to manufacture 50,000 L/d of surface sanitizers by shifting production at its Almásfüzitó plant. MOL is also starting production of sanitizers at sites in Slovakia and Croatia.

Milliken raises production capacity for antimicrobial fabrics

March 23, 2020 — Milliken & Co. (Spartanburg, S.C.; www.milliken.com) has increased domestic production of its BioSmart fabric, which enables practical integration of antimicrobial protection into common medical products.

Arkema augments production in Lyon to donate sanitizer solution

March 20, 2020 — Arkema S.A. (Colombes, France; www.arkema.com) repurposed a production line at its Rhône Alpes Research Center (CRRA), near Lyon, to manufacture 20 m.t./wk of alcohol-based solution to be distributed free of charge to hospitals in France.

Plant Watch

Oxea triples production volumes of n-propanol

April 14, 2020 — In the second quarter of 2020, Oxea GmbH (Monheim am Rhein, Germany; www.oxea-chemicals.com) tripled its delivery volumes of *n*-propanol in Europe due to very high demand from the healthcare and printing industries.

Look for more latest news on chemengonline.com

Unipetrol commissions new polyethylene plant

April 8, 2020 — Unipetrol (Prague, Czech Republic; www.unipetrol.cz) has commissioned the principal parts of a new polyethylene (PE) unit in Litvínov, representing the highest petrochemicals investment ever in the Czech Republic. With the new line, total PE production capacity in Litvínov will expand to 470,000 m.t./yr.

Abengoa to construct large RO desalination plant in Saudi Arabia

April 3, 2020 — Abengoa S.A. (Seville, Spain; www.abengoa.com) has been selected, in a consortium with SEPCOIII, to construct a 600,000-m^3/d reverse-osmosis (RO) desalination plant for Acwa Power in eastern Saudi Arabia. The value of Abengoa's scope in the project exceeds $200 million.

Dow signs MoU to expand Zhangjiagang silicones production

March 27, 2020 — Dow signed a Memorandum of Understanding (MoU) with the Zhangjiagang Free Trade Zone in Jiangsu province, China, facilitating expansion at Dow's manufacturing site in Zhangjiagang. With potential investments of $300 million in the next five years, the MoU intends to increase Dow's capacity to meet global demand for silicone intermediates and finished products.

Showa Denko to set up plant for new aluminum-laminate film product

Showa Denko K.K. (Tokyo, Japan; www.sdk.co.jp) is setting up operations to produce a new aluminum-laminate film product, which is specialized for large-scale lithium-ion batteries (LIBs). Operation of the new production unit is scheduled to start in March 2021.

Mergers & Acquisitions

Nouryon to acquire Sasol's metal alkyls business

April 2, 2020 — Nouryon (Amsterdam, the Netherlands; www.nouryon.com) agreed to acquire the triethyl aluminum (TEAL) business of Sasol Ltd. (Johannesburg, South Africa; www.sasol.co.za). TEAL is a metal alkyl essential in the production of high-volume plastics.

Air Products purchases five hydrogen plants in California and Delaware

March 30, 2020 — Air Products (Lehigh Valley, Pa.; www.airproducts.com) signed agreements with PBF Energy Inc. that include the $530-million purchase of five steam methane reformer (SMR) hydrogen-production plants. The SMRs, with nearly 300 million ft^3/d of combined production capacity, are located in Torrance and Martinez, Calif. and Delaware City, Del.

Ube Industries and Mitsubishi Chemical form JV for Li-ion batteries

March 30, 2020 Ube Industries, Ltd. (Tokyo, Japan; www.ube-ind.co.jp) will establish a joint venture (JV) with Mitsubishi Chemical Corp. (Tokyo; www.m-chemical.co.jp) focused on electrolytes for rechargeable Li-ion batteries. The companies will also integrate research and development and combine intellectual assets. ■

Mary Page Bailey

COVID-19 Shutdowns Slash Demand for Refined Products

Demand for refined products has dropped sharply, challenging petroleum refineries with compressed margins, but a deal was struck on global production cuts

IN BRIEF

The large-scale shutdown of economic activity related to the global pandemic response has caused demand for refined petroleum products to plunge dramatically, placing refiners around the world into a difficult situation. Refinery production cuts are common, while some plants have been idled.

"In countries where stay-at-home orders and social distancing measures have been issued, gasoline demand is down by 50% and aviation fuel demand is down 70% or more," says Steve Sawyer, director of refining for Facts Global Energy (FGE; London, U.K.; www.fgenergy.com). "Diesel demand has kept up a little better because trucking deliveries are still being made, but despite that, diesel has fallen by 30% at least." Sawyer adds "Really, demand for all hydrocarbons coming out of a refinery are down."

Sawyer says April demand for refined products could be 23 million barrels per day (bbl/d) lower than the corresponding value from April of last year. "May could maybe be a bit better, but if you're in a deep hole, and you take one step up, you are still in a deep hole." Weak demand will persist into June, and what happens after that depends in large part on what happens with the public health crisis, he says.

Deal struck on production

The sharp decline in the demand for refined products coincided with oversupply of crude oil that was precipitated by disagreements between Saudi Arabia and Russia in March over reductions in crude production. In April, a largely unprecedented coordinated effort to stabilize global crude oil prices took shape, as Russia, Saudi Arabia and the other nations of the so-called "OPEC-Plus" group (Organization of Petroleum Exporting Countries; www.opec.org, plus allies) finalized a deal on cuts to oil production on April 12.

During a virtual meeting of the OPEC-Plus oil ministers, the group agreed to a reduction in oil production of 9.7 million bbl/d from May 1 to June 30, and called on other oil producers to contribute to the effort. The OPEC-Plus agreement says the cuts will taper to a 7.7 million bbl/d reduction from July to December 2020, and a 5.8 million bbl/d reduction in 2021.

The U.S. also became involved, with President Trump pushing Saudi and Russian leaders for a deal on production cuts and stepping in to help Mexico meet its production cuts. U.S. Energy Secretary Dan Brouillette announced April 10 that the U.S. would open its Strategic Petroleum Reserve to store as much oil as possible. "This will take surplus oil off the market at a time when commercial storage is filling up and the market is oversupplied."

Despite the agreement, downward pressure on oil prices was expected to continue, and crude oil storage facilities are forecast to be stretched. Following the announcement, WoodMackenzie (Edinburgh, U.K.; www.woodmac.com) vice president for macro oils Ann-Louise Hittle said the agreed-upon reduction would support crude oil prices over the second quarter. However, while the announced cuts will offer some degree of relief to the oil industry, they are insufficient to match the demand destruction that has been observed because of the pandemic-related shutdowns, she says.

Further, FGE's Sawyer says there are questions surrounding how the agreement will be implemented in practice, including those of compliance, and inventory levels. Ultimately, all oil market projections beyond the next couple of months depend on the trajectory of global oil demand, which remains at the mercy of COVID-19, FGE says.

As of press time, crude prices remained depressed, with West Texas Intermediate futures trading at $18.27/bbl, for example, and crude inventories rising, according to the U.S. Energy Information Agency (EIA).

'Double whammy'

The supply and demand picture for crude oil products creates a difficult period for refineries. "Most of the time, economic theory states that when prices for a resource go down, we will use more of it. But now, with demand for refined products also dropped because there's less driving and less aviation, we have the unusual situation of low oil prices coinciding with low demand for refined products," comments Arij von Berkel, research director at Lux Research Inc. (New York, N.Y.; www.luxresearchinc.com).

The demand destruction due to the virus, combined with the drop in crude prices was a "double whammy" for refiners, says Sawyer.

"In the current situation, you could produce refined products at a low price, but no one is buying," von Berkel says. "Many refineries are reducing production, or looking to store products in the hopes of selling it later. Refineries may also try to change the product mix, possibly making less aviation fuel and more shipping fuel right now, for example," von Berkel says.

Pandemic response

The response from the refining industry to the pandemic is ongoing, and thus far, it has been multi-dimensional, with operations- and production-related responses accompanied by employee public health measures and humanitarian efforts.

FGE's Sawyer predicts that refinery run cuts related to the COVID-19 shutdowns are going to be at least 15 million bbl/d globally, year over year in April and May. "Some refineries are going to shut as a result of that, temporarily," he says. Examples of refinery shutdowns have been observed in the U.S., Canada, Italy, South Africa and elsewhere. Unfortunately, some of the refineries that have been forced to close because of COVID-19 may struggle to restream, he says.

"We may see shutdowns of fluid catalytic cracker (FCC) units if gasoline demand stays low," Sawyer says. "We have seen some examples of that as well." Some refineries that are in turnaround may not restart for a few months.

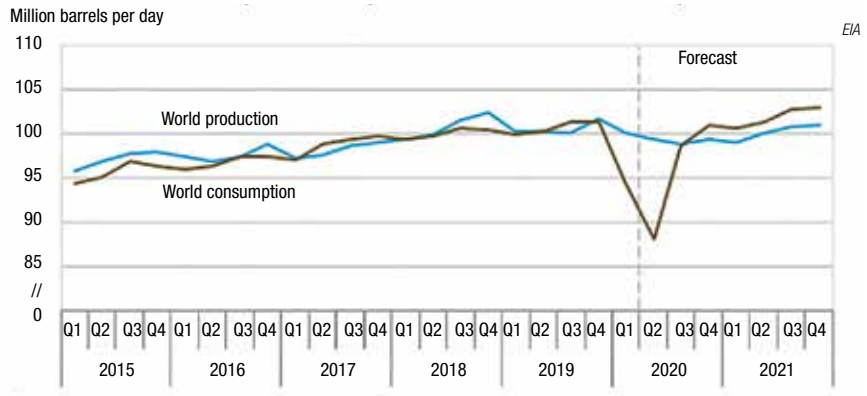


FIGURE 1. Data on global fuels from EIA shows a steep consumption dip in Q2 2020

In the U.S., ExxonMobil Corp. (Irving, Tex.; www.exxonmobil.com) is among many companies with refining operations that have cut production. ExxonMobil cut production at its 502,500-bbl/d Baton Rouge, La. refinery, as low demand has increased inventories and filled storage tanks, the company says. ExxonMobil has also cut contract workers at the site by 1,800 people in April. At least three refineries in California have cut production, as well.

Marathon Petroleum Corp. (Findlay, Ohio; www.marathonpetroleum.com) idled its Gallup Refinery and related assets in Jamestown, N.M. beginning on April 15. Marathon spokesperson Jamal Kheiry says the company does not expect any supply disruptions in the region because it can meet customer commitments with other assets in its network.

"Our intent is to maintain regular employee staffing levels during this temporary idling period, with employees assigned to tasks that are necessary to support our idle status and eventual return to normal operations. At this time, the duration of the idling period is unknown; however, it is our intent to return to normal operations as soon as demand levels justify doing so," Kheiry says. The company would not comment on specific crude acquisitions and refinery runs.

Marathon also provides an example of how large refining companies are handling their personnel during the public health crisis. To reduce the probability of spreading COVID-19 from otherwise healthy people to those most at risk, Marathon has reduced facility staffing to only essential personnel and implemented remote working programs wherever feasible, the company says, adding "This is in addition to a variety of other mitigation efforts, including social-distancing, travel restrictions, self-quarantine guidelines, enhanced cleaning protocols, and more."

On the humanitarian side, many refining companies are finding ways to give back to their local communities. For example, Valero Energy Corp. (San Antonio, Tex.; www.valero.com) Foundation committed $1.8 million in late March to support organizations on the front lines of the COVID-19 treatment and public health response. In addition, Valero is also providing gas cards to selected charitable organizations to provide access to essential fuels and products for their operations. Meanwhile, Marathon donated 575,000 N95 respirator masks to healthcare facilities in 20 states where the company has operations, and through the Marathon Petroleum Foundation, donated $1 million to American Red Cross Disaster Relief.

Preview of the future?

The current demand falloff due to the COVID-19 response is occurring within a larger context of broader demand shifts, and some industry experts are drawing connections between the current situation and what the future might look like 15–20 years from now. Most predictions put the peak global demand for gasoline around 2035, after which demand will decline as a consequence of the automotive fleet changing to electric power or hydrogen, and more efficient internal combustion engines.

"Everyone expects a drop in demand after 2035, which will also be accompanied by a drop in price, so

INNOVATION AND DIGITALIZATION

As refiners try to weather the current public health crisis along with the rest of the world, they are also looking to the future. And a big part of what will shape the future is innovation. A few recent developments on that front include advanced catalysts, R&D capability and digitalization.

Crude laboratory. In January of this year, Clariant Refinery Services (Houston, Tex.; www.clariant.com) opened a new state-of-the-art crude and fuel oil laboratory that focuses on applications for transport and storage. Based in Bradford, U.K., the laboratory supports a highly experienced technical services team equipped to address multiple challenges experienced by refineries, storage terminals, pipeline providers and logistic companies around the world, Clariant says.

The new laboratory has a wide selection of testing regimes and modern methods of crude oil analysis and performance testing. One focus on the facility will be to identify and develop new and customized pour-point depressant (PPD) solutions for the downstream and midstream sectors. Researchers at the laboratory have already developed PPD products and fuel stabilizer solutions specific to the challenges presented by the International Maritime Organization (IMO; London, U.K.; www.imo.org) 2020 regulations, limiting marine fuels' sulfur content to 0.5% from the previous limit of 3.5%.

FCC catalyst. BASF SE (Ludwigshafen, Germany; www.basf.com) launched Fourtune, a new fluid catalytic cracking (FCC) catalyst product for gasoil feedstock. The catalyst is designed to deliver superior butylene over propylene selectivity, while maintaining catalyst activity and performance.

Commercial trials of Fourtune have confirmed its ability to deliver better economic performance through butylene selectivity and high conversion, the company says, and it maintains coke-selective bottoms upgrading and high distillate yields that increases refiners' profitability.

Fourtune is the latest product based on BASF's Multiple Framework Topology (MFT) technology. BASF's MFT technology enhances performance through the use of more than one framework topology that work together to tailor the catalyst selectivity profile, BASF says. Evaluations of the new MFT technology have demonstrated Fourtune's ability to help maximize margins and provide operating flexibility to make more butylene to feed the alkylation unit.

AI refinery project. Artificial intelligence (AI) technology is set to become more widely used in the refining industry. A partnership between BP plc (London, U.K.; www.bp.com) and Beyond Limits (Pasadena, Calif.; www.beyond.ai) has resulted in an "operate-to-plan" project using AI at a BP refinery.

"In many cases, a linear plan for a processing unit is not realizable initially, so engineers have to make it work on the ground, based on what is happening in the plant," explains Kim Gilbert, director of technical sales engineering at Beyond Limits. The AI project started on a naphtha unit with 8–10 distillation towers. The objective was to use AI to help the plant engineers implement their linear plan from AspenTech.

The AI software, which was developed from technology licensed from NASA's Jet Propulsion Laboratory, is using machine learning to identify anomalies and long-term patterns in the data, and connect them to explanations that make sense to operators.

the current situation is almost a rehearsal for 15 years from now," says Lux Research's von Berkel. "It's like a stress test for oil companies. If you want to know how prepared they are for peak demand, have a look at the present."

Following the "standard playbook" response of cutting costs, von Berkel says, "the question then becomes where do you cut costs and where do you stop investing?"

Crude-to-chemicals

While demand for ground transportation fuels will likely decline in coming years, demand for petrochemicals is still forecast to grow.

"The major growth area among hydrocarbons is petrochemicals," says FGE's Sawyer. "Demand for naphtha and LPG [liquified petroleum gas] will increase significantly, but if you look at the supply, there is an increasingly large supply coming from non-refinery sources." For example, ethane from shale deposits is being used as petrochemical feedstock, and there is a significant amount of LPG coming out of crude oil production, rather than from refineries, as well as the inclusion of biofuels and other oxygenates into fuel formulations.

For every 100 barrels of oil in increased demand, there might be only 60 barrels of that coming from a refinery, Sawyer says.

"The future of refining is how they are going to adapt to that. Not only are they challenged to manage the molecules, but also to manage the assets they've got, such as logistical infrastructure, tanks, real estate and so on, to play into the market that is developing," Sawyer explains.

"This is what refiners have done for 100 years, but the challenge is big and it's right in front of us," he notes. Refineries are not dead — out to 2040, there will still be oil demand for 100 million bbl/d, Sawyer says, so refineries will still play a role, but it might be a smaller one. "So that begs the question of what level of investments should be made and what kind of investment should it be and where, and so on."

IMO update

The beginning of 2020 also saw the start of the anticipated regulations from the International Maritime Organization for sulfur levels in shipping fuels, reducing the allowable percentage from 3.5% to 0.5%. For more on the IMO order, see *Chem. Eng.*, May 2019, pp. 16–20.

After a sluggish start in 2018, when the IMO fuel sulfur limits were announced, there was quite a bit of action in 2019, as over 2,000 sulfur emissions scrubbers were retrofitted on existing ships by the end of 2019. The number will rise in 2020 and 2021. Newly built ships will be fitted with scrubbers, or will have the space and the tie-ins to add them easily.

Onboard scrubbers for sulfur emissions make good economic sense when the price differential between high-S fuel and low-S fuel is sufficient to justify the investment. That difference has been there, von Berkel says, but COVID-19 has pushed down crude prices, so the differentials between low-S and high-S fuels are correspondingly smaller. "So the investment [in scrubbers] is still acceptable, but it's not as 'sexy' as it was a few months ago," von Berkel says.

"Up until Q1 of this year, demand has not been that great for the low-S bunker fuels, because people wanted to burn the cheaper, high-S fuel for as long as they could," von Berkel explains. And refiners have generally not invested heavily in making low-S bunker oil. "So the supply of low-S fuel has not been tested. We have to wait for the true supply and demand picture until later this year, but the deadlines went by without a hitch." ■

Scott Jenkins

Wear it Well

Wearable technologies help chemical processors improve productivity and safety of workers

IN BRIEF

Wearable technologies — cameras, tablets and other devices loaded with applications (apps) and software that can be attached to the body or personal protective equipment (PPE) — are catching on in the chemical process industries (CPI) because they provide an efficient way to increase productivity and enhance safety for maintenance technicians and field operators.

Honeywell

FIGURE 1. Honeywell's Intelligent Wearables are android devices that can be hooked through clips to an industrial hard hat and are loaded with software that provides field personnel with the necessary tools and information

Technology drives trends

While the concept is not new, as wearables have been available for years, the technology has dramatically improved, making them more user-friendly, feature-rich and suitable for hazardous environments than previous iterations, opening avenues for use in a variety of industrial applications. Wearables are being applied to enhance maintenance and operator activities by providing digital libraries of necessary documents and over-the-shoulder coaching, and are improving worker safety by supplying location, health and other information about the wearer in an effort to assist with emergency response, mustering and access control.

"Three factors are making wearable technologies more prevalent today: improved devices, the ability to design end-to-end, integrated solutions and better connectivity options," explains Tracey Countryman, managing director and global lead for Industry X.0 Digital Manufacturing and Operations at Accenture (London, U.K.; www.accenture.com). "In the past, the devices were clunky, not suitable for industrial or hazardous environments and were often carried in a heavy metal container that had to be strapped on. However, they've come a long way toward reconciling themselves for the industrial environment. Today's versions are lightweight, durable and have better enclosures, so they can be certified for use in hazardous environments and are available at a better price point."

She adds that by leveraging the newest technologies to build more customized, end-to-end integrated software solutions, facilities are able to digitize the entire work process and load it into a device where workers can access documents, instructions, training videos, work orders and the like via apps and voice commands. The third component is connectivity. "Three to four years ago, only a few plants had WiFi, but now more facilities are employing WiFi for pervasive connectivity. Bluetooth is also widely used and 4G and 5G technologies are available at lower costs, making connectivity a much less expensive, more viable and easier-accessed prospect in industry than ever before," notes Countryman. "These three factors are driving the adoption of wearable technologies for industrial use."

And, statistics demonstrate the anticipated growth. "The Industry 4.0 market opportunity is currently worth $110 billion by total economic value, with Accenture estimating that the industrial internet of things (IIoT) could impact 46% of the global economy, estimated at $14 trillion, by 2030. In the connected worker space, wearable technology and wearable sensor devices alone is growing at a predicted 13.1% compound annual growth rate and is estimated to reach $4.3 billion in the next 20 years," says Mark Bernstein, CEO of Wearable Technologies, Ltd. (Leicestershire, UK; www.eleksen.com), quoting from an Accenture Industrial Internet of Things Positioning Paper Report.

More specifically, Accenture's Countryman, quoting Accenture's Digital State of the Industry Report, adds that when chemical companies were asked how much they'd invest in mobility/wearables in the next 12 months (from 2018), 77% said they'd invest nothing; however, 16% said they'd in-

vest between 21% and 40%. When asked where digital investment for product and operations will be in the next three years, 24% of the top three chemical companies cited mobility/wearables.

"The internet of things is affecting all our lives — small sensors sending data via the internet to and from connected homes, connected cars and connected factories. It is inevitable that most industrial workers in the developed world will, in years to come, wear sensor devices to monitor their health, safety and efficiency," says Bernstein.

But how do wearables help increase productivity and enhance safety? "First and foremost, wearable devices are productivity boosters because most of them can be loaded with digital versions of work procedures and other documents that maintenance technicians and field operators need to do their jobs and these documents and information can be accessed by voice. So instead of carrying binders or a tablet which they have to keep picking up to search for the necessary information and then put down to complete the task, they can quickly locate the information, view the instructions and work on the equipment all at the same time because their hands are free," explains Sanjay Jhawar, co-founder and president of RealWear, Inc. (Vancouver, Wash.; www.realwear.com). "And because you can operate these devices hands-free, they can be used in locations where handheld devices would be inconvenient or impossible to operate due to protective gloves or other PPE or while climbing into a confined space such as a distillation column or vessel, and this is a safety enhancement."

In addition, several available devices include location and other sensors to detect falls, unresponsiveness and dangerous health conditions and assist with mustering, access control and emergency response.

Boosting productivity

One of the biggest productivity benefits associated with wearables is the ability to not only store, but also to easily access, necessary documents and videos, on demand, in the field.

Pepperl+Fuchs

FIGURE 2. Pepperl+Fuchs's Onsight Cube EX is a wearable camera certified for hazardous areas that, along with the Remote Field Expert software feature enabled, allows a person in the field to initiate a video call so they can communicate directly with technical support

"During the digital transformation, we aim to provide customers with digital solutions and opportunities using software, hardware and services that improve safety, productivity and collaboration," says Veronica Turner, business development leader with Honeywell Process Solutions (Houston; www.honeywell.com). "So when we think of field personnel, our Intelligent Wearables — android devices that can be hooked through clips to an industrial hard hat — are an ideal solution. These devices are loaded with software that provides field personnel with the necessary tools, such as forms, P&IDs [piping and instrumentation diagrams] drawings, manuals and libraries of procedures in PDF format, as well as photos and videos, so they can complete tasks more efficiently" (Figure 1).

Accenture's Countryman agrees: "If you go to a chemical plant or [petroleum] refinery today, it is highly paper-driven. There are binders for work orders and work procedures. It is not an efficient process. However, we are seeing a major trend around digitizing work processes, which allows workers to access the needed information and pull up different drawings and instructions in the field to work on a particular asset.

"Wearables allow them to scan barcodes for a particular asset and quickly access operating procedures and real-time information related to that asset, so they can do the work efficiently and properly the first time without going back for tools or information. Today, there's a lot of time spent not having the right information at the right time to do the right work, but people are beginning to look at mobility and wearables to address that issue."

Emerson

FIGURE 3. Emerson's Location Tag can be used to create a virtual fence for access control and mustering purposes

Taking it a step further are applications, such as Video Assist from Honeywell, which allow users to make their own video library of work procedures and break the procedures down into rational steps. "The entire video can be viewed, if needed. However, workers who don't need to watch an entire five minute video, but may need to review just one step in a process, can access only the part they need using voice commands, making it easy to navigate among the steps. Search engine optimization allows procedures to be tagged with key words, so workers can access the information they need," explains Turner.

While it does take effort to add data and work instructions to the software in the devices, it is often worth the effort in increased productivity, according to the experts. RealWear's Jhawar says customers who have done ROI studies often see task time reduced by 40% and error rates reduced by 80%. Likewise, Accenture's Countryman cites their most recent digitalization project, in which the customer sought to improve productivity and maintenance planning. "They had 10,000 pieces of equipment that were barcoded and an integrated, realtime information system

Wearable Technologies

FIGURE 4. Wearable Technologies' Eleksen Connected Worker Solution monitors industrial workforces to improve safety and increase productivity by linking smart garments to a choice of personal sensor devices, such as gas, noise and physiological, to a reporting dashboard that enables managers to monitor the conditions of their workforce in the field and onsite in real time

between document management systems, SAP, work orders and all the associated things that needed to come together to do the work," she says. "After the project, they had 100% compliance with time reporting and they were expecting a 2 to 5% production increase and a 15 to 20% productivity increase. This is in line with what we anticipate for customers who are using wearables for over-the-shoulder coaching and digitizing procedures and other documents."

Live experts on demand

Many of the wearable devices contain a camera along with software that allows field personnel to place a call and connect in real time with an expert selected by the user. Experts are typically control-room personnel, maintenance professionals, vendors or call centers, depending upon who is chosen by facility management. The subject matter expert can guide the field worker by "tele-stration," meaning they can not only see what the field technician is looking at via the camera, but also use the camera to verbally and visually assist the technician by adding drawings, arrows or writing on the image.

"We offer the Onsight Cube EX [Figure 2], which is a wearable camera certified for hazardous areas that, along with the Remote Field Expert software feature enabled, allows a person in the field to initiate a video call so they can communicate directly with tech support on the spot," explains Justin Olivier, product manager for mobility for the Americas with ecom Instruments, a Pepperl+Fuchs brand (Twinsburg, Ohio; www.us.pepperl-fuchs.com).

Olivier provides an example of how a customer with downed equipment on an oil rig used this technology to their advantage. "The technicians on site couldn't find the root cause of the problem causing downtime. The company was contemplating flying an expert out, which was an expensive prospect," he says. "Not only were there associated travel costs, but the rig was losing big money each day the equipment was down. However, they were able to use the Cube and software so the expert could physically see the asset. He was able to provide instructions on the spot. That one application saved the customer hundreds of thousands of dollars from a productivity standpoint because they didn't experience additional downtime while waiting for an expert to be flown to the rig," he says.

Similarly, RealWear had a customer who experienced an explosion that damaged several distillation columns. A complete plant shut down was needed to repair the columns, resulting in very expensive downtime, so there was an urgent need to complete the repair in a short amount of time.

"They purchased a dozen devices and sent subcontractors into the distillation columns to perform the repairs. The contractors wore the devices on their heads and took photos and videos of the work being done

RealWear

FIGURE 5. Wearable devices, such as those provided by RealWear, are productivity boosters because most of them can be loaded with digital versions of work procedures and other documents that maintenance technicians and field operators need to do their jobs — these documents and information can be accessed by voice

so that at the end of the shift, they could transfer the photos and videos to a laptop and have plant personnel audit the work based on the images," says Jhawar. "It streamlined their inspection and approval process, shortening the job by several days and providing payback for the technology in under 72 hours."

This can also provide savings when "witnessing," which is the act of verifying that newly delivered equipment is in working order after installation. "We have customers who use wearables to perform witnessing activities in distant refineries and oil rigs remotely over video call to avoid physical travel," says Jhawar.

Enhancing safety

Wearable technologies also improve safety functions in chemical facilities. "In the industrial markets, there is a growing request for safety products in the wearables realm and for smart PPE, such as technologies for location and access control. In the past, most solutions were extremely expensive to install," says Amanda Alexander, global product manager with Emerson Automation Solutions (Shakopee, Minn.; www.emerson.com). "So we created a product for location technology using the WirelessHART infrastructure and it has removed a lot of the cost, while providing necessary safety benefits."

Emerson offers its Location Tag (Figure 3) for use in geofencing and mustering applications.

Many chemical facilities need to maintain fences for access control around hazardous areas and would prefer to have a virtual fence rather than a physical fence. Using Loca-

tion Tag, they can create a virtual fence and apply certain rules to it. "For instance, if someone is wearing a tag and they do not have permission to enter a particular zone within a facility, an alert will be sent to the appropriate personnel if that person enters that area," explains Alexander. "This also works within the efficiency realm regarding contractors, as it enables facilities to create zones for the contractors by providing them with tags that allow them entrance into only the accessible areas of the facility."

The tag can also be used for safety mustering. "Typically the muster zone is a designated area and when there is an emergency or drill, employees report to the zone, find a supervisor or sign into a sheet that is uploaded and recorded later to determine how long it took employees to reach safety. Simplifying the process, Location Tag creates a muster zone with a virtual fence and when tagged employees arrive, they are automatically counted. On the flip side, if someone does not arrive, an alert is sent and the person can be located by emergency responders using the sensor on the tag. In addition, there is a button on each tag that can be pressed in the event of emergency or injury to send an alert over the user interface."

Wearable Technologies, too, is using wearables to keep industrial workers safer by delivering data-led, actionable insights in real time to site managers and health and safety managers. "We are delivering big data relating to workers, to the data lakes already holding other types of data such as plant and weather data to facilitate the application of artificial intelligence across the large enterprise," says Bernstein. The company's Eleksen Connected Worker Solution (Figure 4) provides the ability to monitor industrial workforces to improve safety and increase productivity by linking smart garments to a choice of personal sensor devices, such as for gas, noise and physiology, to a reporting dashboard that enables managers to monitor the conditions of their workforce in the field and onsite in real time, helping mitigate risk, reduce costs and improve performance.

As wearable technologies continue to improve, they will become an extension of Industry 4.0, connecting not just plant data and analytics, but that of worker productivity and safety, as well. "If you think of sensors as instrumenting the plant itself, it's not a great leap to think of them as instrumenting the humans operating the plant. And, if you can combine IoT from humans and IoT from the plant, then you will have a complete picture of your operations," says RealWear's Jhawar (Figure 5). "This is important because the maintenance and reliability performance of the manufacturing operation depends upon how well the field technicians maintain the assets, as well as their safety. At the end of the day, it's all about the effectiveness and efficiency of how the people in the field interact with the assets that gets processors to best-in-class operating performance. Wearables are all about helping individuals be the best version they can be because they have access to best-in-class knowledge at all times." ■

Joy LePree

Focus on Maintenance Tools

Software determines when to maintenance RO systems

This company has developed a new normalization software for analyzing reverse-osmosis (RO) equipment. PerforMem automatically imports system data from templates in standard process control systems and quickly normalizes even large volumes of data. PerforMem also provides a much more detailed graphical representation of process data and normalized values. Normalized values can then be converted to various formats for further processing or analysis if necessary. Whenever membrane processes suffer from falling retention or reduced performance, this could be due to changes in the water quality or temperature, or deposits in the RO system. The collection of plant data in a cloud in combination with remote maintenance makes economic sense no matter what size the plant. The data can be used for process optimization and troubleshooting. — *Lanxess AG, Cologne, Germany*
www.lanxess.com

Predictive maintenance tool for gas analyzers


ABB

Scheduled to have been launched this month at the Hannover Trade Fair (which has been cancelled due to COVID-19), Ability Condition Monitoring for measurement devices (photo) is a digital solution that will keep continuous gas analyzers under control to ensure clean-air operations. The new digital solution keeps track of the health of this company's measurement devices. Performing realtime data analysis, the Ability Condition Monitoring for measurement devices identifies problems quickly, drawing attention to significant or undesirable changes in device conditions. Regular health-check reports provide users with recommendations based on health status, allowing on-site personnel to leverage their own expertise and enabling remote assistance from the company when required. Predictive maintenance reduces users' potential safety risks and helps them avoid fines. It also lowers operating and maintenance costs due to less emergency maintenance and fewer unplanned outages. — *ABB Ltd., Zurich, Switzerland*
www.abb.com

A liquid cleaner for manual or automated washing operations


Madison Chemical

ProClean PAN WASH (photo) is a liquid moderately alkaline cleaner designed for use in the food-, dairy- and beverage-processing industries. It is well suited for use in pan washing equipment or as a soak cleaner, and for automatic washing of dairy and beverage cases. This proven formulation is effective and free-rinsing in hard or soft water. ProClean PAN WASH is safe for use on aluminum, stainless steel and other ferrous alloys when used as directed, may etch and attack zinc alloys, including galvanized. ProClean PAN WASH is acceptable for use in food and beverage plants as an A2 cleaning agent for use only in soak tanks, with steam or mechanical cleaning devices in all departments. — *Madison Chemical, Madison, Ind.*
www.madchem.com

Machine health solution optimizes pumps and systems

This company is expanding its intelligent solutions range with the launch of Grundfos Machine Health (GMH) powered by Augury, a realtime analytics and diagnostics solution that provides accurate and actionable in-house analysis on rotating equipment for industrial, water utility and commercial applications. The GMH system gives users unprecedented control over downtime prevention. Using advanced wireless sensors to monitor pumps and systems, data are transferred to a secure cloud platform where a robust algorithm detects the slightest vibration, temperature variations and magnetic flux. Any abnormality is translated into a straightforward, actionable task and sent to the maintenance team. Through the completion of these tasks, users can expect improved longevity for equipment, increased operational efficiency and less downtime for their equipment. — *Grundfos, Houston*
www.grundfos.us

Remove oil stains from concrete with this cleaner

Cortec Corp.

This company's MCI line focuses on corrosion protection for reinforced concrete, and also includes several specialty products that provide excellent companions for concrete or construction site maintenance. One of these is MCI-2061, a powerful cleaner (photo) that safely and effectively cleans oil stains on concrete using "green" chemistry. It is said to be an excellent and effective alternative to harsh caustic or acidic cleaners. Initial cleaning is due to biodegradable surfactants in the product. Ongoing cleaning action is performed by microorganisms that activate when applied to pre-wetted concrete and rinsed according to instructions. These microorganisms are specially selected for their ability to biodegrade hydrocarbons, such as those found in oil, diesel and other materials that stain concrete. Spores that remain after rinsing germinate and continue to eat away at the residual hydrocarbons not removed in the initial cleaning process. MCI-2061 microorganisms carried away with the rinse water can also work to clean up hydrocarbons downstream in drains and sewers. — *Cortec Corp., St. Paul, Minn.*
www.cortecvci.com ■

Gerald Ondrey

Note: For more information, circle the 3-digit number on p. 66, or use the website designation.

New Products

These metering pumps feature a very large turndown ratio

The Flexflow A1F peristaltic metering pump (photo) is designed for metering off-gassing chemicals, such as sodium hypochlorite and peracetic acid. The pump offers a smooth chemical feed without risk that it will overheat or lose its prime. Furthermore, the pumps do not require continuous maintenance and do not include any check valves that could potentially clog. A large turndown ratio (1,000:1) allows users to standardize on one pump for all chemical-feed applications. Feedrates up to 5.6 gal/h (21.19 L/h) and pressures up to 100 psi (6.89 bars) are achievable. Other features include a sealed weatherproof enclosure, a patented tube-failure-detection functionality, mounting brackets and a self-adjusting power supply. — *Blue-White Industries, Huntington Beach, Calif.*

www.blue-white.com

New IIoT platform for instrumentation management

Netilion (photo) is a new industrial internet of things (IIoT) ecosystem that improves lifecycle and asset management, maintenance and support of instruments and analyzers. Users can manage their installed base by accessing documentation and data related to instruments' performance and health status. Netilion currently offers several digital services: Scanner, which is a smartphone application (app) that guides the user in capturing field-instrument asset data; Analytics, which can create a digital twin of a system; Health, which visualizes the diagnostic data provided by an instrument and tracks an instrument's condition so that maintenance can be optimized; Library, which is a file-sharing and data-management service for the complete lifecycle of an instrument; and Value, which is a monitoring service that collects process data from the field. These digital services can be used separately or in concert to improve the management, maintenance and support of instrumentation systems — regardless of type or vendor. — *Endress + Hauser, Greenwood, Ind.*

www.us.endress.com

Process monitoring where space is at a premium

The LiquiSonic Lab 3-in-1-sensor (photo) is designed for reactors and small plants in laboratories and technology centers. Directly flanged into the reactor lid, the device monitors sonic velocity, attenuation and temperature with high precision. LiquiSonic sensors can be used for monitoring complex polymerization or crystallization reactions. Harsh conditions, such as high temperature (160°C) or pressure (16 bars), can also be handled. Process kinetics can be monitored inline and even under extreme process conditions in pressurized miniplants or pilot reactors. Space-saving design, separated sensor electronics and a user-friendly, multilingual controller with powerful data memory characterize the LiquiSonic system. Sensor materials include Hastelloy HC2000, tantalum or titanium to protect against corrosion and promote long process life. — *SensoTech GmbH, Magdeburg–Barleben, Germany*

www.sensotech.com

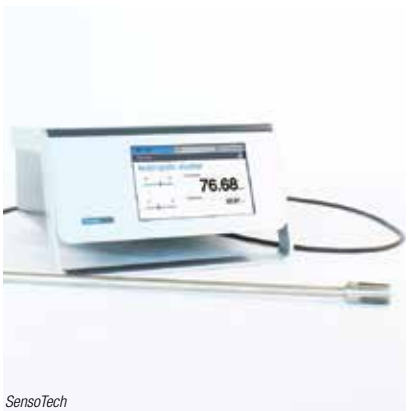
Maximize energy recovery from sludge-handling processes

The DTR Series of double-tube heat exchangers (photo) is designed specifically for use with low-viscosity sludge products as the heating or cooling medium. This configuration makes DTR exchangers suitable for direct sludge-to-sludge heat recovery in wastewater-treatment operations. The DTR Series performs well with fluids that contain particles, without creating blockages that impede flow. Special stainless-steel corrugated tubes are used to increase heat transfer and reduce fouling. This allows the product or waste stream to run in both the inner and outer tubes. It also allows for easier and faster cleaning, so overall there is less operational downtime, even with high-fouling products. The inner tube of the exchanger is removable for inspection, cleaning and maintenance, meaning that both the tube- and shell-sides can be inspected and cleaned. For large installations, multiple units can be interconnected and mounted in a frame. — *HRS Heat Exchangers Ltd., Hertfordshire, U.K.*

www.hrs-heatexchangers.com

Blue-White Industries

Endress + Hauser



SensoTech

HRS Heat Exchangers

Hardy Process Solutions

New intrinsically safe weighing instruments

The HI 8100IS and the HI 8200IS are high-performance weighing instruments (photo) designed to operate in all Classes, Divisions and Groups in accordance with U.S. Underwriters Laboratories (UL), American National Standards Institute (ANSI) and CAN Standards. Both instruments feature two available power options: a.c. line power for permanent installation in the hazardous area; or high-performance external rechargeable battery packs that are easy to switch out for recharging in the safe area. For continuous battery power, maintaining multiple batteries allows for fast swapping in and out. The HI 8200IS is an advanced indicator with checkweighing features for manufacturing processes where equipment operates near flammable gases; flammable or combustible liquid-produced vapors; or combustible dusts or ignitable fibers. The HI 8100IS is a basic five-button indicator designed for use in hazardous locations. The HI 8100IS is suitable for a range of weighing demands, from tank-based inventory control to batching operations. — *Hardy Process Solutions, San Diego, Calif.*

www.hardysolutions.com

Hans Turck

Siemens Digital Industries

Ethernet communication for Ex areas

The first Zone 2 Ethernet gateway for this company's excom I/O system, the new GEN-3G excom gateway (photo), brings signals from Zone 0 at high data rates to the control system. For the first time, all process data can reach IT systems for analysis and evaluation at sufficient speed via a parallel data channel, which is a fast and easy way of implementing condition monitoring and predictive maintenance. The new GEN-3G multiprotocol device operates at high data rates in Profinet, Ethernet/IP or Modbus TCP networks without the need for manual intervention. The integrated gateway switch enables the implementation of linear topologies that can be connected easily in the network to form a ring. Besides the hardware redundancies for power-supply units and gateways, excom also supports redundancy concepts, such as S2 system redundancy to ensure maximum availability. — *Hans Turck GmbH & Co. KG, Mülheim an der Ruhr, Germany*

www.turck.com

Ozopure Italia

New 80-GHz radar level transmitters are also compact

The new Sitrans LR100 series 80 GHz radar transmitters (photo) are compact instruments with a narrow beam for flexible installations in existing vessel openings or even non-intrusively through plastic vessels. The transmitters' 80-GHz frequency delivers robust, reliable measurements even in challenging environments, such as those with vapors, condensation, turbulence or solids, says the company. The custom microchip technology delivers fast response and extremely high sensitivity to detect even the weakest of signals, the company adds. The series consists of three products: Sitrans LR100 for basic measurement to 8 m; Sitrans LR110 with communication and hazardous approvals options and range to 15 m; and Sitrans LR120 with communication (longest range to 30 m) and optional submergence shield for flooding protection. — *Siemens Digital Industries, Nuremberg, Germany*

www.siemens.com

The launch of a next-generation ozone technology

After four years of development, this company is now launching a new ozone-generation technology that solves many of the drawbacks associated with conventional O_3 technologies. The new O_3 generator (photo) features a flat-plate reactor that does not use glass, and has no corrosion problems. The system has a small footprint, low energy demand, high reliability and produces O_3 with high efficiency and concentration, says the manufacturer. The system is suitable for use in the wastewater treatment, drinkable water, pharmaceutical and food-and-beverage industries for applications such as sterilization and disinfection in bottling processes, reverse osmosis, marine systems, cooling towers, laboratories and more. — *Ozopure Italia S.R.L., Fano, Italy*

www.ozopureinternational.com

Improved sealing makes this heat exchanger more efficient

Thanks to a patent-pending sealing concept, the new Compabloc+ heat exchanger (photo) ensures safe operation with no risk of media leaks at pressures up to 60 bars — representing a 20-bar increase over previous Compabloc models. The sealing concept is a first-of-its-kind for bloc-type heat exchangers, featuring a fully-confined graphite gasket, rather than a traditional flat gasket. This change makes it possible for Compabloc+ to safely handle higher operating pressures than possible in the past, while simultaneously simplifying maintenance by protecting against overtightening and creeping. Compabloc+ is a more energy-efficient alternative to traditional shell-and-tube heat exchangers and can replace up to four shell-and-tube units for the same duty, according to the manufacturer. — *Alfa Laval AB, Lund, Sweden*

www.alfalaval.com

A conveyor designed to handle hazardous materials

This company's Tubular Chain Conveyor (photo) reliably contains dusty and hazardous materials, safeguarding workers at the same time as protecting the conveyed material from external influences. It is also resistant against internal pressure buildup and helps to contain propagating flame, making it suitable for handling potentially explosive chemicals. By using a low-horsepower motor, energy consumption is considerably less than traditional pneumatic conveyors. Constructed from chemical-grade stainless steel and other FDA-approved components, the conveyor comprises a fixed drive and tension assembly, which automatically tensions the chain continuously during the process and regulates it according to friction, product flow and variation in atmospheric or product temperature. — *Luxme International Ltd., Brossard, Canada*

www.luxme.com

Alfa Laval

Luxme International

R. Stahl

UL-certified control stations for extreme temperatures

This company has obtained updated UL approval for its explosion-protected Ex e (increased safety) control stations from the 8146 and 8150 Series (photo), as well as its ConSig 8040 range of control and signaling stations for use in an extended ambient temperature range. This means that 8146/55 Series control stations are now suitable for use across North America in hazardous (classified) locations at ambient temperatures between –50°C (–58°F) and 40°C (104°F). The 8150/5 Series of control stations, which is made out of stainless steel, has been approved for temperatures as low as –60°C (–76°F) and up to 85°C (185°F). The robust enclosures, which are available in different dimensions, can be individually configured and equipped with control devices, indicator lamps, illuminated pushbuttons, control switches, ammeters and voltmeters. — *R. Stahl, Waldenburg, Germany*
www.r-stahl.com

Cowan Dynamics

Introducing a new range of valve actuators

Launched in March, the E2HR Series Electro-Hydraulic Rotary valve actuators (photo) feature a very small installation envelope for ¼-turn valve-actuating applications. All hydraulic components and sensors are integrated into a single compact manifold block that also houses the actuator and integral oil reservoir. The control panel can be mounted directly to the manifold block or installed remotely to run multiple units from a single control panel. This self-contained actuator can be installed either vertically or horizontally and has no external piping. It is available for on/off or modulating applications and for a wide range of markets and valve applications. The valves' operating-temperature range is –50 to 40°C, and they offer very low power consumption and tight shutoff. — *Cowan Dynamics, Inc., Montreal, Quebec, Canada*
www.cowandynamics.com

Mary Page Bailey and Gerald Ondrey

Nucleation Processes in Crystallizers

Department Editor: Scott Jenkins

Industrial crystallization processes are widely used in the chemical process industries (CPI) for their ability to separate and purify products in a single step, often to greater than 99.9% purity. Crystal growth proceeds after nucleation, a molecular aggregation process whereby nuclei act as the centers for crystallization. This one-page reference provides information about the chemistry and physics of the nucleation step in crystallization processes, and its ultimate impact on solid crystal structure.

The period between the establishment of supersaturation and the formation of nuclei in the solution plays a decisive role in determining the properties of the resulting solid products, including purity, crystal structure, polymorphic form and particle size. The type of nuclei that are formed and their rate of formation also influence the particle-size distribution of the crystal population, and other properties of the crystals, so control of the nucleation process is crucial in obtaining the required product specifications [*1*].

Cluster formation

For nucleation to occur, solute molecules that are dispersed within the solvent must form clusters at nanometer scales that persist (are stable) under the given operating conditions. Supersaturation refers to a state in which a higher amount of solute is dissolved in a volume of solvent than would be predicted based on the solubility characteristics of the substance at a given temperature. Initiating a phase change to begin crystallizing the solute can be achieved by further increasing the concentration of solute, or decreasing the temperature. Supersaturation is a prerequisite condition in crystallization operations. The spontaneous appearance of a new phase can occur only when a system is in a nonequilibrium condition. Molecules dissolved in solution begin to aggregate to relieve the supersaturation and move the system toward equilibrium [*2*].

TABLE 1. SECONDARY NUCLEATION MECHANISMS (ADAPTED FROM REF. 1)

Secondary nucleation type	Characteristics
Initial breeding or dust breeding	• Usually occurs if dry seed crystals are introduced into a solution • Dry handling of the seed crystals causes small fragments by attrition that adhere to the dry seeds. These fragments are liberated from the surface in the solution, and become new nuclei • It is recommended to suspend fresh seeds in an undersaturated solution to dissolve the fragments before feeding the seeds as a slurry to the (generally batch) crystallizer
Dendritic breeding	• Only happens at such high supersaturations that facet instabilities occur during outgrowth of the crystals • This implies that the corners and edges of the crystals experience a higher supersaturation than the middle of the faces (facets) and hopper-like crystals or even dendrites are formed • These protruding crystal parts easily break off and become secondary nuclei
Contact nucleation or attrition breeding	• The most important source of secondary nuclei in a crystallizer, and results from collisions between crystals and impeller blades, between crystals and vessel walls and from mutual collisions between the crystals • The secondary nuclei are formed by attrition of the crystal corners, edges and macro-steps on the surfaces
Fluid-shear breeding	• Formation of secondary nuclei due to shear forces in turbulent fluid that are exerted on a crystal surface • Very high shear forces are, however, needed to exceed the yield stress of a parent crystal leading to the formation of an attrition fragment. This breeding mechanism is thus considered to be less important

Primary nucleation

In primary nucleation, crystals form without the presence of other crystals. This can occur homogeneously, where nucleation is not influenced by solids, including crystallizer vessel walls or particles of foreign substances; or heterogeneously, when solid particles of foreign substances cause an increase in the nucleation rate. In industrial practice, homogeneous nucleation is rare because it requires high energy to initiate nucleation without a solid surface. Most primary nucleation in industrial crystallization processes is heterogeneous, induced by foreign solid particles present in working solutions.

Secondary nucleation

Secondary nucleation refers to the formation of nuclei under the influence of existing microscopic crystals, where the birth of nuclei occurs at the interface of parent crystals. Secondary nucleation is the dominant mechanism in industrial crystallizers, and several types of secondary nucleation are possible (Table 1).

Contact nucleation, the most important source of secondary nuclei in a crystallizer, results from collisions between crystals and impeller blades, between crystals and vessel walls and from mutual collisions between the crystals. The secondary nuclei are formed by attrition of the crystal corners, edges and macro-steps on the surfaces. In this model, secondary nucleation is determined by crystal collisions. The number of nuclei produced upon the impact of a crystal is assumed to be proportional to the impact energy [*1*]. The rate of nucleation is then equal to the product of the collision energy and the frequency of collisions in a specific size range.

Attrition of the outgrown crystals provides fragments that either dissolve or grow into the crystal population. In evaporative and cooling crystallization, secondary nucleation is thus the source of new crystals.

Secondary nucleation occurs at lower degrees of supersaturation than primary nucleation, which allows control of crystal growth rate to optimize product quality; as well as lower energy, which avoids excessive breakage of existing crystals. ■

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Vinyl Chloride Production from Ethylene and Chlorine

By Intratec Solutions

Vinyl chloride (also known as vinyl chloride monomer, VCM and chloroethene) is an organochloride compound. At room temperature, VCM is a gas with a sweet, ethereal odor, but in industrial processes, it is most often handled as a liquid (melting point = –13°C). VCM is a major commodity chemical, mainly used in the production of the polymer polyvinyl chloride (PVC). For this use alone, VCM is among the top 20 petrochemicals in world production. To a lesser extent, VCM is used in furniture and automobile upholstery, wall coverings, housewares and automotive parts.

The process

This analysis describes the production of VCM from ethylene and chlorine via a balanced process (Figure 1). The process comprises four major sections: (1) oxychlorination; (2) direct chlorination; (3) ethylene dichloride (EDC) cracking; and (4) purification.

Oxychlorination. Hydrogen chloride (HCl) is reacted with ethylene and oxygen, yielding EDC and water. Oxychlorination is conducted above 200°C. High conversion and selectivity are obtained with metallic chloride catalysts. The EDC obtained is partially condensed and compressed before it is fed to a series of columns for purification. High-boiling and low-boiling compounds are recovered and converted to CO_2, water and HCl, which is recycled to the reaction.

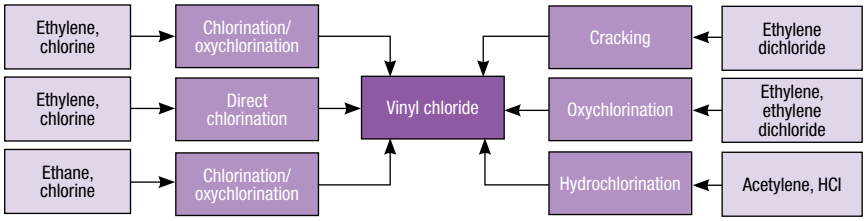

FIGURE 2. Several pathways exist for making VCM

Direct chlorination. Ethylene is chlorinated to produce EDC. The direct chlorination reaction is carried out in the liquid phase, using EDC itself as the solvent. The reaction is conducted with a slight excess of ethylene, leading to a conversion of almost 100% and selectivity higher than 99%.

EDC cracking. EDC from the direct chlorination and the oxychlorination reactions is preheated, vaporized and thermally cracked to yield VCM, HCl and unreacted EDC. 60% conversion of EDC is typical, with selectivity to VCM greater than 96%.

Purification. The VCM obtained is partially condensed before it is fed to a series of columns, where HCl, EDC, VCM and impurities are separated. Hydrogen chloride is recovered and recycled to oxychlorination. Unconverted EDC is returned to EDC purification, while VCM product, with acidity content below 0.1 ppm, is stored.

Production pathways

Originally, production of VCM on a commercial scale was based on the reaction of HCl with acetylene derived from calcium carbide. Throughout the 20th century, as ethylene became plentiful, new production routes for VCM were developed, with ethylene and chlorine as main raw materials. Figure 2 presents different pathways for VCM production.

Economic performance

The total operating cost (raw materials, utilities, fixed costs and depreciation costs) estimated to produce VCM was about $500 per ton of VCM in the second quarter of 2016. The analysis was based on a plant constructed in the U.S. with the capacity to produce 500,000 metric tons per year of VCM.

This column is based on "Vinyl Chloride Production from Ethylene and Chlorine – Cost Analysis," a report published by Intratec. It can be found at: www.intratec.us/analysis/vinyl-chloride-production-cost. ■

Edited by Scott Jenkins

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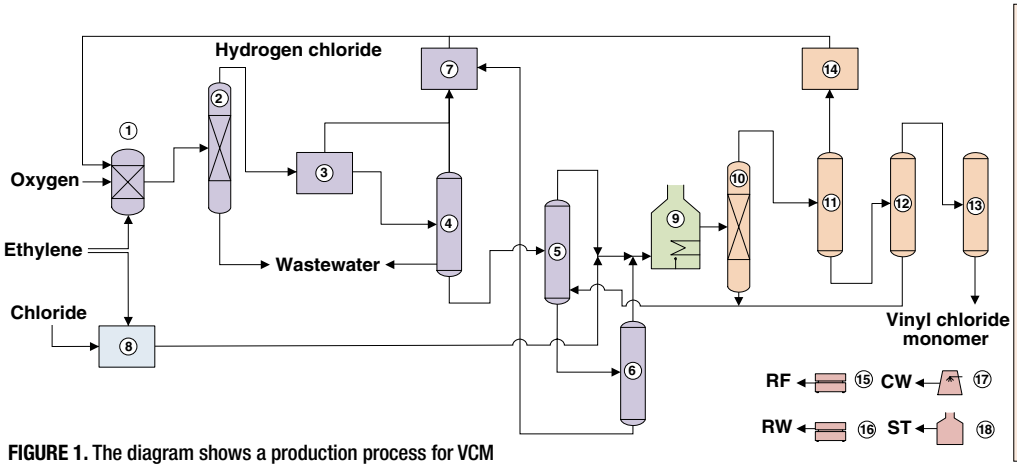

1. Oxychlorination
2. Oxychlorination quench
3. Condensation & compression
4. Heads column
5. High-boil column
6. Vacuum column
7. Byproduct recovery
8. Chlorination reactor
9. EDC cracking
10. EDC quench
11. HCl column
12. VCM column
13. HCl stripper
14. Hydrogenation
15. Refrigeration system
16. Chiller
17. Cooling tower
18. Boiler

RW Chilled water
CW Cooling water
RF Refrigeration fluid
ST Steam

FIGURE 1. The diagram shows a production process for VCM

Part 1

Low-Cost Techniques for NOx Reduction

An understanding of the available NOx-reduction strategies will help engineers to select the best technique to improve the performance of their combustion processes

Joseph Colannino
Colannino Consultants LLC

IN BRIEF

Pollution due to oxides of nitrogen — frequently abbreviated as NOx — is regulated with varying degrees of severity in different localities. NOx regulations are regional for good reason: NOx and hydrocarbons react in a complex way to produce smog, and smog formation is greatly affected by topological and meteorological conditions. NOx reduction to very low levels carries economic impact, and balancing environmental and economic requirements has been a mainstay of air-quality legislation since its inception. There are many inexpensive and historically validated NOx-reduction techniques that can cut NOx in half, as dicsussed in this article.

FIGURE 1. Process heating units in petroleum refineries are governed by air-quality regulations to control NOx pollutants

NOx regulations are complex and vary by industry, fuel type, equipment and region. Some parts of the U.S. require NOx emissions at or below 9 parts per million (ppm) for some stationary sources, such as boilers and steam generators, while other equipment and regions are less regulated. Remediation requirements vary nationally from routine maintenance and tune-ups to selective catalytic reduction (SCR) strategies, and these differ widely in cost. However, for many regions, stationary NOx sources, such as furnaces, steam boilers and generators and petroleum-refinery process heaters, NOx reduction to around 40 ppm remains adequate (Figure 1). Before discussing particular strategies, it is important to understand the general principles behind NOx formation.

Why do industrial flames produce NOx?

NOx from industrial combustion comprises nitric oxide (NO) largely. There are three mechanisms for producing it. In the case of fuels that contain no nitrogen in the parent molecule (for example, natural gas), the Zeldovich mechanism produces most of the NOx. This may be approximated by the following integrated rate expression:

$$[\mathrm{NOx}] = A[\mathrm{N_2}] \int_0^t e^{-\frac{b}{T}} [\mathrm{O_2}] d\theta \qquad (1)$$

where the brackets indicate the volume concentration of the enclosed species, A and b are constants, t is the total reaction time (with θ serving as the dummy variable in the integration), and T is the absolute temperature. So NOx from this mechanism depends on three primary quantities — temperature, oxygen concentration and reaction time — and minimizing any or all of them will reduce NOx. Since temperature is exponentially weighted, the peak flame temperature has an oversized role in NOx formation.

If a significant number of fuel molecules contain nitrogen bound in their structure, the overwhelming share of NOx will be formed from the fuel-bound mechanism, leading to a rate equation as shown in Equation (2):

FIGURE 2. NOx formation in industrial-combustion units is dependent on the quantity of excess oxygen present, the peak flame temperature and the fuel type

$$[NO_x] = \kappa \int_0^t [C_xH_yN][O_2]d\theta \qquad (2)$$

where κ is a constant. Since the reaction is fast, and the fuel concentration is limited by the required stoichiometry, fuel-bound NOx formation may be reduced only by reducing the excess oxygen or switching to lower-nitrogen fuels.

The third NOx-formation mechanism is the Fenimore mechanism, also called prompt NOx. It is similar to the fuel-bound mechanism, except that the nitrogen comes directly from the combustion air. Since nitrogen radicals are exceptionally difficult to pare from molecular nitrogen, prompt NOx from this mechanism is usually negligible and is discussed no further here.

NOx-reduction strategies

From the NOx formation discussion above, we see that NOx may nearly always be reduced in greater or lesser measure by reducing the excess oxygen concentration and peak flame temperatures, or by a change in fuels, if possible (for instance, from high-nitrogen fuel oil to low-nitrogen fuel oil or from fuel oil to natural gas). Here then, are nine case-specific NOx-reduction strategies:

1. Burners out of service
2. Derating
3. Oxygen and combustibles trim
4. Tramp air reduction
5. Steam or water injection
6. Staged combustion
7. Alternate fuels
8. Fluegas recirculation
9. Low-NOx burners

Each strategy is discussed in this article. However, and as with any change in operating procedure regarding fired equipment, a full safety review must be conducted prior to any operational or physical change. Fire is inherently dangerous. Site-specific factors beyond the scope of this article may impact safe operation. It is incumbent upon all practitioners of these techniques to use care in their application in order to avoid loss of life, limb and equipment. If plant expertise is lacking, one should seek the assistance of a qualified combustion professional.

Burners out of service

A burners-out-of-service strategy is applicable to multi-burner systems only. As an example, consider a front-fired boiler having two horizontal rows of three burners each (three over three). By simply closing the fuel valve to the upper center burner, the fuel is redistributed from six burners to five, while the air is distributed equally to all six. This causes the local stoichiometric air ratio to shift toward more fuel-rich for the five remaining burners. This reduces the local excess air and peak flame temperatures, thus lowering NOx. The air register on the unfired burner is left to operate as usual, bringing the global air-to-fuel ratio to normal and providing the balance of air to oxidize CO generated by the local fuel-rich conditions. Flames may lengthen with this procedure. Normally, there is sufficient excess boiler capacity and furnace volume to accommodate this change. Notwithstanding, care must be taken to verify that no flame impingement to equipment occurs as the result of the change, especially at higher firing rates. Usually, the center burner at the highest elevation makes the most NOx and is a primary candidate for this strategy.

Derating

Sometimes, a plant has excess fired capacity. For the sake of calculating emissions, air-quality districts always presume that permitted fired

FIGURE 3. Different types of NOx-producing equipment may be subject to varying measurement conventions, depending on their location. For instance, boilers in the U.S. may measure NOx in terms of lb produced per million Btu of heat released

equipment is continually operating at nameplate capacity. If it happens that the plant has excess capacity, it may choose to permanently derate some equipment in order to take advantage of less stringent regulations. This is not sophistry. If the equipment operates for fewer hours or at lower rates, it genuinely produces fewer mass emissions. Accordingly, some air-quality districts are willing to allow higher NOx concentration limits if firing rates are permanently reduced or operating hours are genuinely curtailed. Usually, the district will impose monitoring, recordkeeping and inspectable physical or control restrictions in exchange for higher permitted NOx concentrations over shorter durations or at lower maximum rates. This prompts a discussion about how NOx is calculated.

Different conventions exist for measuring NOx. In Europe, NOx is often expressed on a grams-per-normal-cubic-meter-of-effluent basis (g/Nm^3). In the U.S., units include pounds per million Btu of heat released (lb/MMBtu) for boilers (Figure 3), grams per brake horsepower (g/BHP) for stationary engines, tons per megawatt-hour (ton/MWh) for electrical utility boilers, parts per million on a dry volume-corrected basis (ppmvdc, or less specifically, ppm), among many other units. Despite this sea of units, NOx metrics divide into only two categories: a concentration basis; or a mass basis normalized by the firing rate. Mass-based units are relatively immune to confusion, but concentration-based units are more ambiguous. For example, if NOx is 40 ppm but is measured in a leaky stack (typical), influent air will dilute the NOx to read a lower concentration, despite the lack of any real reduction in the mass emissions rate to the atmosphere. To avoid this ambiguity, NOx units are corrected to a reference volume per the following dimensionless equation:

$$\frac{y_{\mathrm{NO}x,c}}{y_{NOx,m}} = \frac{21\% - y_{O2,r}}{21\% - y_{O2,m}} \qquad (3)$$

Here, $y_{\mathrm{NO}x,c}$ is the mole fraction of the corrected NOx, $y_{\mathrm{NO}x,m}$ is the NOx measured at the stack exit, 21% is the concentration of oxygen in air (some districts use 20.9%), $y_{O2,m}$ is the mole fraction of oxygen measured at the stack, and $y_{O2,r}$ is the mole fraction of some reference oxygen. For boilers and the like, this reference is usually 3% excess oxygen. For example, if NOx measures 35 ppm at a stack oxygen of 5%, then it would be reported as 39.4 ppm referenced to 3% oxygen; that is, 35 ppm [(21% – 3%)/(21% – 5%)] = 39.4 $ppmvdc_{3\%}$, or 39.4 ppm for short. Now, whether the stack leaks or not, one may report NOx consistently. Note, to convert from $ppmvdc_{3\%}$ to lb/MMBtu, scale by the proportion 0.05 lb/MMBtuh = 40 ppm.

Oxygen and combustibles trim

Most industrial burners separately meter fuel and air, and are known as diffusion burners because the fuel diffuses into the air as the combustion reaction takes place. Indeed,

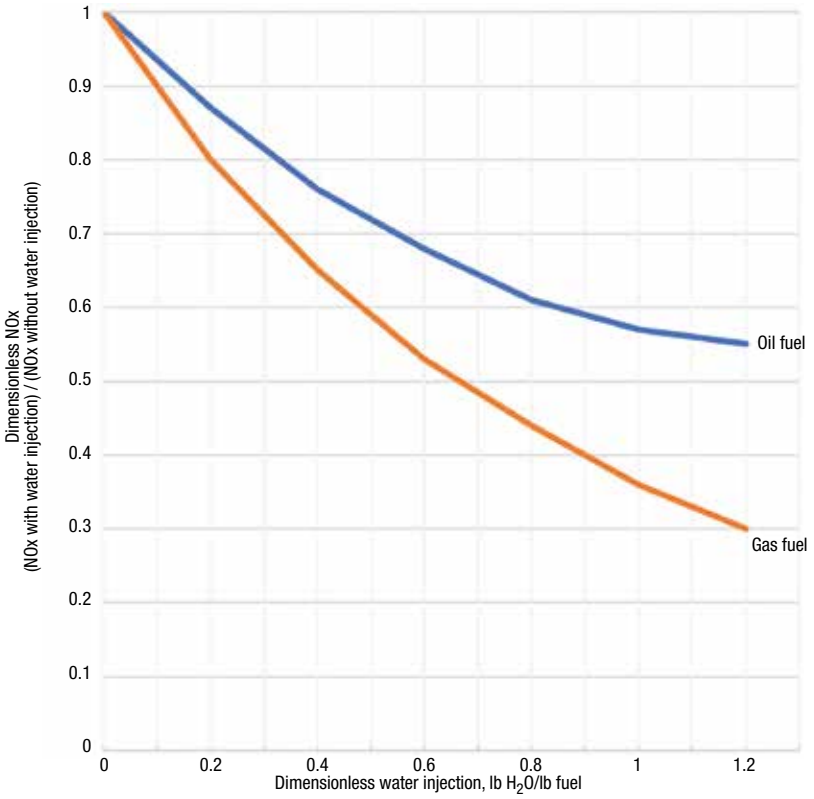

FIGURE 4. Water injection is an effective method for reducing NOx levels

this diffusion process is generally what sets the flame dimensions inasmuch as the flame chemistry is very fast but the diffusion is much slower. Once the diffusion is complete, the flame ends. Typically, the fuel issues through orifices and the combustion air comes through a much larger surrounding inlet, often modulated through louvered registers or air dampers. Conventional diffusion burners (burners not designed to minimize NOx) usually mix their air and fuel as rapidly as possible to produce short, compact flames. This was the rule for burners dating from the 1970s or before, many of which are still in service. While this results in compact flames, it also results in high NOx, owing to the high heat release over short distances that elevates peak flame temperatures and NOx formation. It is not uncommon for such burners to generate 100 $ppmvdc_{3\%}$ of NOx, or more. However, temperature is not the only factor.

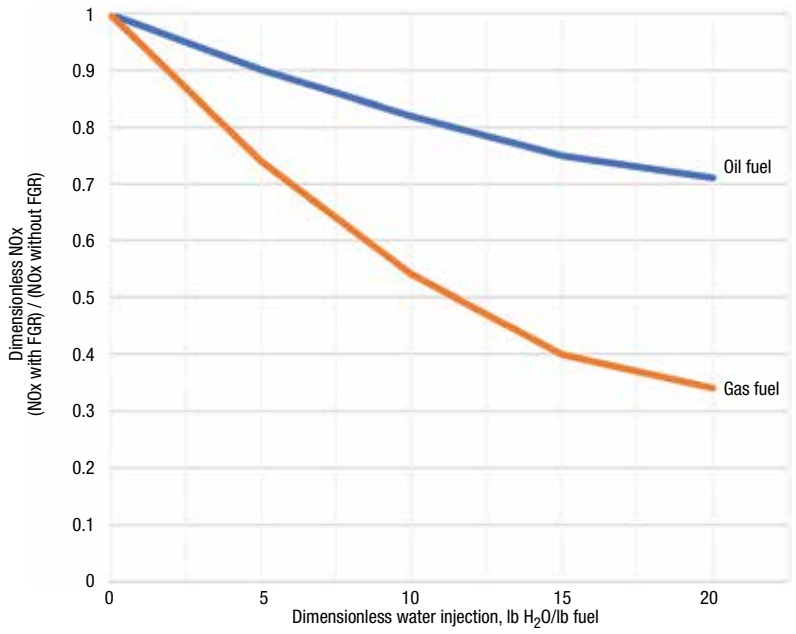

FIGURE 5. The benefits of fluegas recirculation (FGR) in NOx reduction are twofold: first, FGR reduces the starting oxygen concentration; and second, FGR abstracts heat and lowers the flame temperature

As shown in Equation (1), NOx is also affected by the local oxygen concentration. For example, a boiler generating 100 ppmvdc when operating at 3% O_2 may generate 150 ppmvdc when operating at 6% O_2. This is not a dilution effect — here, NOx is consistently reported on a dry-volume-corrected basis in both cases; rather, this is an effect of chemistry. More available oxygen generates higher rates of NOx formation according to Equation (1). Many burners rely on mechanical linkages between fuel and air valves to apportion the fuel and air. However, and in the interest of safety, these are set conservatively. The result is that more air is admitted than is strictly necessary. Oxygen trim enables the air registers to trend to a specific target. This minimizes NOx production.

What should the target excess oxygen be? A general rule of thumb is 3%, but for well-maintained and well-behaved boilers, the oxygen may be set lower, and for poorly maintained boilers, even 3% may be inadequate. Lower oxygen reduces NOx and increases boiler efficiency because one is minimizing the amount of excess air to be heated and ultimately discarded. However, some level of excess air is always required for a number of reasons: first, because mixing is never perfectly efficient, so some excess oxygen is always needed. More importantly, one cannot know from oxygen measurements alone whether the oxygen is right or woefully inadequate. Many incorrectly presume that if the boiler or furnace runs out of air, the flame will go out, but that is not the case. Combustion reactions continue, even with woefully inadequate oxygen, producing copious quantities of carbon monoxide and unburned

hydrocarbons — a potentially explosive and toxic mixture. To avoid this calamity, it is best to monitor both oxygen and combustibles. The technology is well practiced and inexpensive. An oxygen trim system will reduce oxygen to a target level, and the combustibles trim will act to increase or reduce the oxygen setpoint to assure minimal levels of combustibles. These actions increase efficiency and minimize NOx formation and are superior to purely mechanical fuel-air ratio systems.

Tramp air reduction

An old gardening adage states that "a weed is a plant out of place." In a similar vein, tramp air is air admitted out of place. In general, combustion engineers desire all the air to pass through the air register so that it will fully participate in the combustion process. Tramp air is air admitted through leaks in the boiler or furnace casing, broken seals or weldments, holes due to corrosion and so on. This air does not participate efficiently in the combustion process. The result is that boiler operators are forced to add more air through to the burner in order to reduce flame length, to be sure that all the fuel is oxidized and so on. The results are high global levels of excess oxygen and higher NOx. For negative-pressure units, one may find tramp air using a hollow probe comprising ¼-in. (6-mm) tubing connected via a flexible hose to a pressure gage designed to indicate a vacuum of around ¼ in. of water column. Then, one uses the probe to check seams, penetrations and other areas of interest. A deflection in the gage indicates a leak, which may often be sealed on the spot with high-temperature silicone caulking. Reducing tramp air will force more air through the burner, resulting in better behaved flames and lower NOx. The probe may also be used for positively pressurized furnaces as well, though the source of such leaks is often obvious even without a probe, as evidenced by discoloration on the casing and other similar signs. Repair is usually not possible during operation for positive-pressure units. Nonetheless, one may mark the location with high-temperature ink or paint to signal its repair for the next unit outage.

Staged combustion

If air and fuel are more gradually mixed in a burner, the flame tends to lengthen and transfer more of its radiant heat to the process. Since radiative heat transfer is a fourth-order process, the hot spots in the flame will give up their heat more quickly than their cooler counterparts. The result is a reduction in NOx via radiative cooling of the flame. One may stage fuel, air, or both. In fuel staging, air is added incrementally in two or three stages. The initial portion is used to stabilize the combustion and reduce prompt NOx, while the remainder is added after some combustion has taken place, resulting in lower local oxygen concentrations and reduced Zeldovich NOx.

Air staging uses a complementary approach, where the air is divided into early and late portions. Staged combustion of any kind tends to lengthen the flame and radiatively cool it while lowering local oxygen concentrations, reducing NOx. It is often the case that existing burners may be modified to stage a portion of their combustion by a combustion engineer skilled in the art. One may also buy a low-NOx burner that already makes use of staged-combustion principles.

Steam or water injection

Sometimes, NOx is very close to, but not quite below, a mandated level. For example, suppose a furnace produces 43 ppm on some occasions, but that NOx regulations mandate 40 ppm or below. One may replace the burner with a low-NOx version. But sometimes the expense may be avoided by injecting a small portion of steam or water. Either will reduce the concentration of oxygen by dilution and reduce NOx (Figure 4). Steam also has about double the heat capacity of air, meaning it will reduce the flame temperature — another important factor in NOx reduction. Water injection has an additional advantage in that the latent heat of vaporization will carry even more heat away from the flame. Actually, these techniques can substantially reduce NOx. The reason for using them only for more marginal adjustments is because they carry an efficiency penalty — additional heat is being carried out of the stack in the form of water vapor rather than being transferred to the process and because too much steam or water can quench the flame. Using only enough steam or water to reduce NOx by 10% or so often keeps this efficiency penalty to a percent or two, which is tolerable for industrial boilers. If fuel costs are not a significant part of the production cost, NOx may be lowered by greater amounts.

Alternative fuels

Sometimes, higher nitrogen-containing fuels may be swapped for fuels with lower nitrogen levels — for example, using lighter rather than heavier fuel oils, or swapping light fuel oil for natural gas. Many burners are equipped to burn both liquid and gaseous fuels, so such a switch may be possible.

Fluegas recirculation

One source of inert diluent is the fluegas itself. Generally, some portion of the fluegas is plumbed to the air inlet to reduce oxygen concentration in the windbox from 21% to some lower level, say 18%. Most conventional burners can tolerate inlet air containing 15 to 20% fluegas by volume, and most air fans have sufficient excess capacity to draw air from the stack to an inlet, providing that the recirculating conduit is appropriately sized. Fluegas recirculation (FGR) can make significant reductions in NOx even when used on conventional rather than low-NOx burners (Figure 5). The reductions occur, first because FGR reduces the oxygen concentration and second, because fluegas that is cooler than the exhaust will also abstract heat and lower the flame temperature. Additionally, the increased mass flow acts to homogenize the flame, increasing mixing and further reducing peak flame temperatures. These effects conspire to significantly reduce NOx.

Low-NOx burners

Low-NOx burners (LNBs) are a ready-made solution and can obtain sub-40 ppm NOx quite easily. Indeed, there are low-NOx burners operating in conjunction with FGR that achieve sub-10-ppm NOx levels. Of the nine options considered here, this is the most expensive, albeit with certain advantages. First, manufacturers stand behind their low-NOx burners with performance guarantees, and one should not purchase them otherwise. Second, LNBs may be purchased turnkey. In that case, remedies may be specified for failure to meet performance and schedule. This is especially important when performance delays will result in real revenue loss, such as for mission-critical units.

Implementation

A good combustion consultant can often identify initial problems and corrective actions from an initial inspection. Then the unit should be characterized to correlate NOx emissions against firing rate and oxygen concentration. Nowadays, portable NOx measurements are reliable and relatively inexpensive, and many emissions-testing companies are available for this type of work. A characterization will provide a baseline, let you know how far away you are from your required target and inform your choice of NOx-remediation strategies. Once you have your baseline, it is advisable that facilities start with the lowest-cost NOx-reduction options and work forward. Deciding which option is the least expensive is somewhat case-specific. However, strategies such as tramp air reduction, burners out of service for multiple-burner units and steam and water injection are relatively easy to try. Oxygen and combustible trim systems are cost-effective and likely to pay for themselves in short order. Practical strategies for particular facilities are usually not difficult to determine. Once they are implemented, the unit is retested to validate the fix. Most of these techniques will result in NOx reductions of 50% or more, and combinations of strategies are likely to result in further reductions. ■

Edited by Mary Page Bailey

Editor's Note: This article follows a previous article written by the author, Low-Cost Techniques Reduce Boiler NOx, which was published in *Chemical Engineering* in February 1993. Figures 4 and 5 here have been adapted from the 1993 article. See the online version of this article at www.chemengonline.com for additional related content.

Author

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Part 2

Turning Up the Heat on Valve Train Safety

Despite their nearly universal use in industrial combustion processes, valve trains are not widely understood. Here are some guidelines to help ensure their safe and effective operation

Robert Sanderson
Rockford Systems, LLC

Does your manufacturing facility have a smoke stack? If it does, it also likely contains a valve train, commonly known in industrial circles as a fuel train. This complicated series of piping and components needs regular inspections, accurate record-keeping and preventative maintenance to avert very serious safety and productivity issues (Figure 1).

If you aren't sure what a valve train is, you're not alone. It is one of the most misunderstood pieces of equipment in a plant, even by those conducting work on it. As a result, it rarely receives the consideration it should from plant managers and safety professionals. While it is not necessary for engineers to know every engineered component of a valve train, they should be aware of what it does and why it demands attention.

Essentially, a valve train controls the flow of pressurized gases into fuel-fired industrial equipment (Figure 2). For safe and proper combustion, the flows of air and gas to the burners are controlled by the valve trains feeding the burners. The burners then mix the combustible gases and release the thermal energy needed to safely heat furnaces, boilers, heating, ventilation and air-conditioning (HVAC) equipment, thermal oxidizers and other equipment to a specified temperature. In turn, the fuel-fired equipment performs critical industrial tasks, such as drying gypsum boards, roasting and baking foods, heat-treating metals, heating fluids and abating pollution.

What could go wrong?

Owing to the presence of hazardous vapors and gases, a poorly designed or inadequately maintained valve train can lead to catastrophic accidents, ranging from explosions and fires to employee injuries and death. When this explosive force is unleashed, the shockwave carries equipment, debris, materials, pipes and high temperatures in all directions with tremendous force.

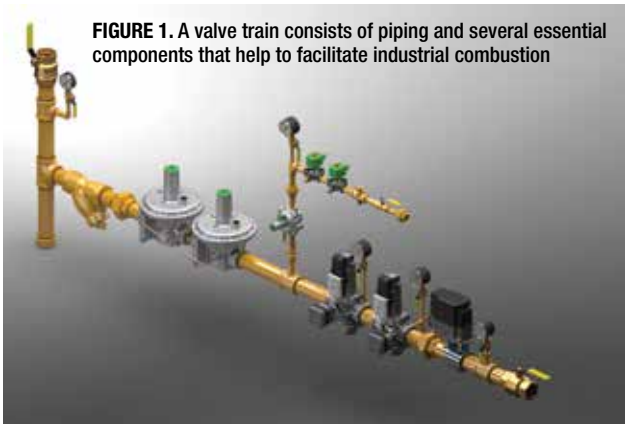

FIGURE 1. A valve train consists of piping and several essential components that help to facilitate industrial combustion

The following incidents are examples of why it is important to use a high-quality valve train, and to keep it professionally maintained, inspected and tested:

- In 2018, a furnace explosion at a Massachusetts vacuum-systems plant killed two workers and injured firefighters as a result of fuel malfunction
- In Japan, an automobile manufacturer lost tens of millions of dollars when it was forced to shut down production for almost a month after a gas-fueled furnace exploded due to flammable fumes building up in the tank
- In a Wisconsin bakery, an employee was seriously injured when he ignited an oven's gas and was struck by a door that was blown off. A malfunctioning valve had allowed natural gas to build up inside the oven
- In 2017, a van-sized boiler exploded at a St. Louis box company, killing three people and injuring four others. The powerful, gas-fueled explosion launched the boiler more than 500 feet into the air
- In 2016, a boiler explosion in a packaging factory in Bangladesh enveloped the five-story building in flames, killing 23 people

The need for maintenance

Many such explosions are the result of a lack of maintenance. Valve trains, like all industrial equipment, wear with use. The following are some considerations that should be taken into account when maintaining valve trains:

- Fuel flowing to a system can convey condensate, piping scale or other foreign materials that will either damage or block a safety valve from fully closing
- Diaphragm valves are vulnerable to embrittlement, aging and rupture
- Outdoor valve trains must endure seasonal extremes, adverse weather and exposure to ultraviolet (UV) light

- Control valves and linkages may loosen with cycling
- Debris accumulates in fans, burners and air piping, altering air-to-fuel ratios and reducing energy efficiency
- Incorrectly vented valves, relief devices, regulators and pressure switches can fail to properly respond upon use, or not react at all
- Gas pressure switches should be wired with a means to prevent fuel from a failed switch from flowing through a conduit or wiring to an electrical enclosure. Such a failure could cause an explosion if the fuel were to reach an arcing contact inside the electrical system
- If plug valves are installed, they must be properly serviced with the correct sealant. Plug valves that are low on sealant may leak externally, or permit fuel to bypass a closed valve. Excessive use of sealant can build up in the piping, which may subsequently flow into other components
- Worse yet, an employee may defeat, bypass or jumper-out safety controls, creating unknown hazards

Add up all these dangers and the need for maintenance by trained technicians becomes readily apparent.

Inspection requirements

Different components of the valve train may be on their own unique inspection frequencies set forth by the manufacturer or established by codes. It is strongly recommended, however, that the entire combustion system be inspected at least annually, both internally and externally while out of service, to assure compliance. Consult with the specifications set forth in NFPA 86 (Standards for Ovens and Furnaces) from the National Fire Protection Association (NFPA; Quincy, Mass.; www.nfpa.org) as a starting point. It provides guidelines to establish these measures, clearly stating: “The user has the responsibility for establishing a program of inspection, testing and maintenance with documentation performed at least annually.”

NFPA 86 applies to both new installations and modifications to existing equipment. Yet because NFPA 86 is only a minimum standard, the Authority Having Jurisdiction (AHJ) has the final say. The AHJ could be an insurer or the local fire marshal, for instance. Whoever it is, the AHJ is the point of definitive reference for all compliance matters.

Does this mean that you are in the clear if the AHJ gives your valve train approval? The short answer is no. Annual testing and preventive maintenance are typically requirements of insurance agencies, but other (often overlapping) codes and standards may need to be adhered to in addition to NFPA. These may include codes from industry organizations, such as the American National Standards Institute (ANSI), American Society of Mechanical Engineers (ASME), National Electrical Code (NEC), the Underwriter’s Laboratory

FIGURE 2. Valve trains serve the essential purpose of controlling the flow of pressurized gases into fuel-fired equipment

(UL) and the U.S. Environmental Protection Agency (EPA).

A final word of caution: if you are in a location that does not mandate ASME CSD-1 (Controls & Safety Devices for Automatically Fired Boilers) or NFPA 85 compliance, the AHJ will rarely address fuel-system issues. Testing the interlock and gas train is typically assumed to be a responsibility of the owner. Therefore, an AHJ saying your boiler or dryer "passed" will bring no assurances that the valve train is compliant.

Questions to ask

Owing to the presence of hazardous vapors and gases, poorly designed or inadequately maintained valve trains have led to catastrophic explosions, fires, asphyxia and burns, not to mention property losses running in the hundreds of millions of dollars. Thankfully, you can significantly reduce the potential for accidents by asking your plant or safety manager five simple questions, which are outlined in the following sections.

1. Does the valve train receive an annual inspection? The entire combustion system must be inspected at least annually, both internally and externally, to assure compliance (Figure 3). NFPA 86 provides guidelines to establish these measures, clearly stating: "The user has the responsibility for establishing a program of inspection, testing and maintenance with documentation, performed at least annually." This applies to both new installations and modifications. Annual testing is typically required by insurance agencies, but facilities may also need to adhere to other (often overlapping) codes and standards besides NFPA — for example those set forth by ANSI, ASME, NEC and the EPA. For instance, oil-fired burners must comply with UL-296 Standard for Oil Burners, UL-726 Standard for Oil-Fired Boiler Assemblies, or UL-2096 Standard for Commercial/Industrial Gas and/or Oil-Burning Assemblies with Emission Reduction Equipment.

Only a qualified outside contractor should perform annual inspections. This company will test, assess, maintain and replace necessary components of the gas train, leaving you with a system that is code-compliant. In addition, accurate record keeping by both the outside contractor and your maintenance team will allow you to follow trends in train performance.

The more that engineers learn about the potential dangers of a valve train, the greater peace of mind they will enjoy knowing that the one on their plant's floor has been thoroughly inspected.

2. How is the combustion system being purged? Purging airflow ensures that any flammable vapors or gases that might have entered the fuel-fired equipment during shutdown are cleared. Two basic requirements must be satisfied: purge airflow and purge time. Purge airflow can be tested by using a metering device or by measuring a drop in pressure. The second purge requirement is testing the purge timer, which is set to a calculated duration to exhaust an accumulation of hazardous gases from the chamber. The time required for purging is determined by the volume of the equipment. Typically, this requires four complete volume changes, but may require as many as five to seven cycles to displace the combustible gases. If the timing cycle or purge airflow gets interfered with during purge testing, you must restart and conduct a new full purge.

3. Are any components missing from the train? As mentioned earlier, valve trains are complex devices

FIGURE 3. An annual valve-train inspection should be comprehensive to ensure that all components are operating efficiently and safely, and meet the necessary industry standards

made up of a series of components, each one dependent on the last. Even the most basic train will feature safety shutoff valves, manual shutoff valves, high- and low-pressure switches, pressure taps and inline strainers. Add to this regulators, valve-leak test systems, upstream and downstream gages, and you can recognize the potential for missing parts, either by design or by accident. Your plant manager's maintenance records should indicate if alterations to the original equipment were made.

Two components that are often missing from inspected trains are a basic sediment trap and strainer. These are typically installed before other horizontal components in the train. These devices protect the gas-train components from pipeline debris, such as pipe scale, teflon tape, excessive sealant and condensates, but some manufacturers do not include them unless specified. Other components that are commonly omitted are high and low gas-pressure switches. These switches shut off power to the burner in the event that gas pressure is below or above the setpoint. Often, it is an untrained maintenance member being pressured to get a boiler or furnace up and running immediately who may bypass a switch.

4. Is the valve train vented or ventless? Regrettably, unless valve-train components are listed as "ventless," vent lines are necessary. These lines must be correctly engineered, installed and routed to appropriate and approved locations. Even when vent lines are properly installed, building pressures can vary sufficiently enough that they prevent optimal burner performance. Vent pipes have also been known to fill with spiders, bees and other insects. If plugged, the pipes will not allow the devices to freely breathe, or for venting gases to escape outside.

In short, vent lines are another point of potential failure for a combustion system. Lines must be inspected regularly by the maintenance staff for leaks or blockages. When given the choice, always go with correctly engineered, ventless components.

5. How are emissions being controlled? Reducing emissions has become a major focus in many industries and geographical locations, especially in California. Often, meeting new EPA or revised local requirements necessitates modifications to existing valve trains — for instance, installing a new low-NOx burner nearly always requires a new valve train to more precisely control the flow of gases. If plants are not current with the latest regulations, agencies may issue hefty fines or shut down production completely until modifications are made.

Calculating and setting up air-to-gas ratios, also known as "burner tuning," can significantly reduce the amount of NOx, CO, CO_2 and particulate matter being released into the atmosphere by a combustion system. Switching fuels or changing the constituents of the fuel also impacts environmental performance. Natural gas burns cooler than fuel oils and has no nitrogen in it, making it a lower producer of NOx. This is a major reason why it has rapidly replaced fuel oils.

Valve trains are critical to the operation of combustion systems. Despite being used in thousands of industrial facilities, awareness of their purpose and function may be lacking because onsite training is minimal or informal. To many employees on the plant floor, this series of valves, piping, wires and switches is too complex to take the time to understand, and what is known can be dangerously misunderstood. ■

Edited by Mary Page Bailey

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Steam Quality Considerations

Steam often provides the majority of heat, but its quality is not always carefully managed. Here are some tips on how to improve and maintain steam quality

James R. Risko
TLV Corp.

IN BRIEF

Plant operations focus on production activity, maintaining tight control on process algorithms, feedstocks and equipment. Steam often provides the majority of heat, but its quality is not carefully managed. Do engineers consider all distributed steam to be equal in quality?

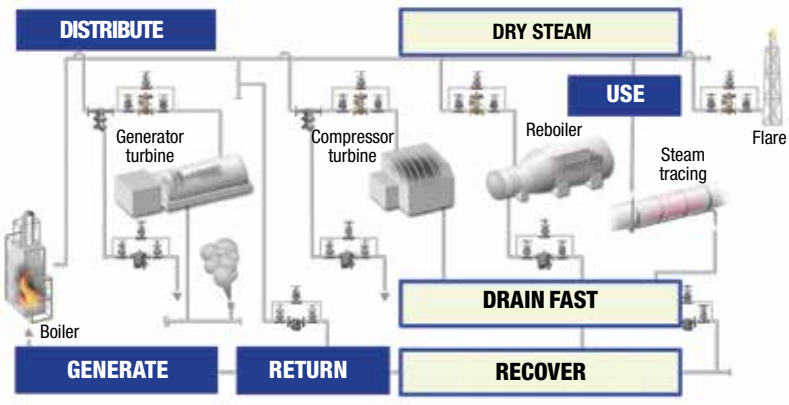

FIGURE 1. A steam system has four stages: generate, distribute, use and return of recoverable energy. Equipment performs best with dry steam and when condensate is drained quickly. Recovered energy reduces boiler load

There are several questions I like to ask when meeting with steam engineers or operators for the first time, such as the following:

- If you were the plant manager, would you want to optimize production value?
- Would you willingly accept off-specification feedstock or equipment?
- Where does the plant get the majority of heat used in production?
- If the answer is, "steam," is it superheated, saturated or wet?

The typical answer to the last question is, "We have all three types of steam." That's when I tell them that their answer is impossible, there is no such thing as sustainable saturated steam in a production plant. "Your steam is *wet*."

Because steam is wet, one further question arises, "How can a plant optimize production if their steam heat asset is in a suboptimal condition?"

Steam quality should be optimized for reliability and efficiency purposes, otherwise critical systems and equipment can deteriorate. Some examples of areas that can suffer from the negative effects of wet steam include the following:

- Turbine plating, silica deposits, erosion, trips
- Vacuum jet erosion, high energy use, low vacuum
- Stripping steam poor quality
- Flare tip erosion, meter trips, flare-outs, poor control
- Atomization steam wetness
- Soot blowing issues on boiler tubes
- Gland seal steam damage
- Control valve erosion
- Pipe erosion, particularly elbows and tees
- Orifice erosion

To mitigate against such issues, steam quality should and can be improved, but it does require an understanding of the importance of two key requirements in a steam

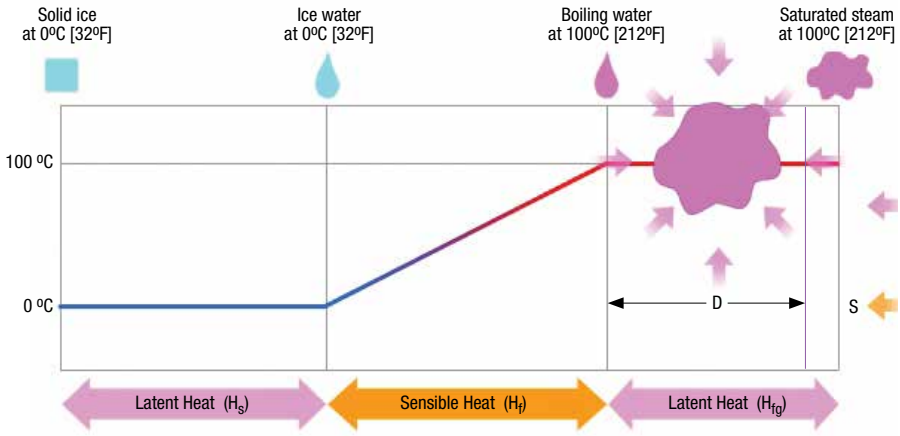

FIGURE 2. Heat energy is needed to change state and elevate temperature. Phase changes occur when ice becomes water and water becomes steam. Steam exits boilers with a certain amount of wetness (3–5%, not saturated)

system: 1) proactively maintain a minimum threshold of "good" condition steam traps with high priority [*1, 2*]; and 2) implement mechanical separation equipment for critical processes as needed.

Look at your heat asset

Plant steam is the major source of heat for most chemical and refining processes, yet it often receives little attention relative to its quality. Perhaps this is the result of commonly referring to plant steam as, "saturated." Statements such as the following are typical: "We have 650 psig superheated steam, and three levels of saturated steam, 150, 50, and 15 psig. The use of the word "saturated" is so prevalent, it can easily become a replacement for what is actually present in the plant. That is, plant steam is either superheated, or wet steam at saturation temperature. Why is this so important? If engineers and other plant personnel believe that most of their steam is saturated, it might be difficult to envision the importance of dealing with normal wetness — and this can have a profound effect on plant operations and efficiency.

How is steam used?

Steam has four stages, generation, distribution, use and return (Figure 1). Once it is in the use stage, it is important to have the steam as dry as possible, to drain condensate quickly after steam's heat has been transferred to the process, and to recover the remaining heat and treated water from the process to return it to the boiler, thereby reducing the burden on the boiler and its impact on the cost of heating and treating raw make-up water.

Why is plant steam wet?

The phase changes that occur with water are shown in Figure 2 [*3*]. There are three phases, solid/ice, liquid/water, vapor/steam. While the temperature remains the same (0°C, 32°F) at atmospheric condition when converting ice to water at the point of freezing, it takes a certain amount of "latent" heat energy to change a mass of ice completely to water. If only some of the required heat is provided for a phase change, there would still be bits of ice in the subject mass — but the temperature remains the same (amount of added heat is unclear or hidden).

Once the full ice mass has been converted to liquid, theoretically it is now water at freezing temperature, and it is no longer ice. This ice-cold water is unsaturated — it has ability to absorb heat and still remain in a completely liquid state up until water's saturation temperature, also known as its boiling point (100°C, 212°F). While adding heat between the point of ice water and boiling, each increase of heat raises the water's temperature. It is why this region's heat is known as "sensible." By recording its temperature and mass, it is possible to mathematically calculate or sense

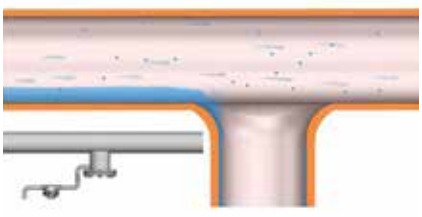

FIGURE 3. Steam contains condensate, both entrained in vapor, and disentrained flowing along the bottom of the pipe as a liquid stream. Only already disentrained condensate is removed through condensate discharge locations

the total amount of heat in the not-yet-saturated (unsaturated) water.

Once water is saturated, adding heat converts some of its molecules to steam — up until the point known as "saturated" steam, when all molecules have been converted to vapor. However, during this phase between saturated water and saturated steam, it is not clear exactly how much heat has been added because steam — wet or saturated, is formed at the same temperature as saturated water. The actual heat amount is hidden, hence the term, "latent heat." Perhaps this is why steam is commonly referred to as saturated, when in fact, it is wet steam at saturation temperature — the same saturation temperature as both boiling water and steam.

Saturated steam from boilers?

Do boilers produce saturated steam? The direct answer is, "no." Boiler steam has 3–5% wetness caused by water adhering to the outside of the steam bubbles as they break through the surface of water while exiting the boiler. There are methods that can be used to improve the quality of exiting steam, but even with those, the steam is not 100% dry and also experiences some heat loss during the distribution stage [*4*].

Once wet steam is produced, it can be passed through a superheater, which removes all wetness while crossing over the saturated steam threshold, and then increases its temperature, volume and total heat content. Superheated steam has a low specific heat content, so commonly its benefit is realized when obtaining high temperature or dryness, not added

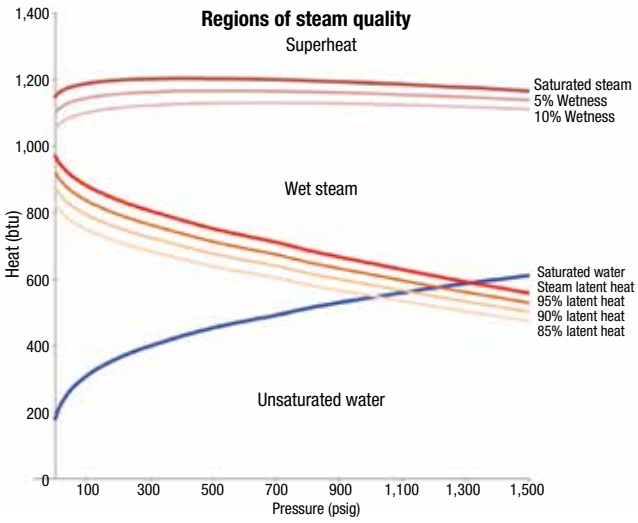

FIGURE 4. Entrainment affects the amount of latent heat per unit of mass that is provided to equipment. 10% or 15% entrainment reflects a significant decrease in heat capability, and can create reliability problems in certain equipment

heat. Typical uses are for high process temperature demand, or to drive turbines.

Distributed steam is key

When discussing steam distribution, the topic invariably leads to the importance of mitigating against water hammer. While such avoidance is critical to safe operation, it is only part of the story [*2*].

Water hammer examples normally only show the liquid condensate that has already been disentrained from the steam flow. It rarely considers the wet steam droplets that are part of a wet steam mixture, and how adversely those droplets can create issues that affect operational efficiency and reliability (Figure 3) [*5*]. A review of how wet steam reduces reliability of specific equipment is provided later, but first additional information about steam wetness is provided. The specific enthalpy of steam can be calculated using Equation (1):

$$h_g = h_f + (D \times h_{fg}) \quad (1)$$

Where:
h_g = Steam total heat
h_f = Sensible heat
h_{fg} = Latent heat
D = Steam dryness, %

Consider Figure 4, which shows the regions of steam quality and heat values. The dark blue line represents saturated water, with the area under this line representing the region of unsaturated water. This water line demonstrates that as pressure increases up to 10.35 MPa (1,500 psig), additional heat must be added to reach boiling.

The red line represents the latent heat — the heat of steam that is used for most process applications. Latent heat decreases in the graph as the pressure increases. The higher the pressure, the less steam heat is available. The mustard-colored lines under the steam latent heat line are most important because they demonstrate the reduction in latent heat for a given

STEAM CHARACTERISTICS VARYING DRYNESS %

Pressure (psig)	Temperature (°F)	Sensible heat (Btu)	Latent heat (Btu)	Total heat (Btu)	Dryness
200	**388**	**362**	**838**	**1,200**	**100%**
200	388	362	**796**	**1,158**	**95%**
200	388	362	**754**	**1,116**	**90%**
200	388	362	**737**	**1,099**	**88%**
150	**366**	**339**	**858**	**1,196**	**100%**
150	366	339	**815**	**1,153**	**95%**
150	366	339	**772**	**1,110**	**90%**
150	366	339	**755**	**1,093**	**88%**
100	**338**	**309**	**881**	**1,190**	**100%**
100	338	309	**837**	**1,146**	**95%**
100	338	309	**793**	**1,102**	**90%**
100	338	309	**775**	**1,084**	**88%**
50	**298**	**267**	**912**	**1,179**	**100%**
50	298	267	**866**	**1,133**	**95%**
50	298	267	**821**	**1,088**	**90%**
50	298	267	**803**	**1,070**	**88%**
15	**250**	**218**	**946**	**1,164**	**100%**
15	250	218	**899**	**1,117**	**95%**
15	250	218	**851**	**1,069**	**90%**
15	250	218	**832**	**1,050**	**88%**

STEAM CHARACTERISTICS DRYNESS AFTER 98% MOISTURE REMOVAL

Pressure (psig)	Sensible heat (Btu)	Latent heat (Btu)	Less 98% H_2O (Btu)	Total heat (Btu)	Ending draness
200	**362**	**838**	**838**	**1,200**	**100%**
200	362	**796**	**837**	**1,199**	**99.9%**
200	362	**754**	**836**	**1,198**	**99.8%**
200	362	**737**	**836**	**1,198**	**99.7%**
150	**339**	**858**	**858**	**1,196**	**100%**
150	339	**815**	**857**	**1,195**	**99.9%**
150	339	**772**	**856**	**1,194**	**99.8%**
150	339	**755**	**855**	**1,194**	**99.7%**
100	**309**	**881**	**881**	**1,190**	**100%**
100	309	**837**	**880**	**1,189**	**99.9%**
100	309	**793**	**879**	**1,188**	**99.8%**
100	309	**775**	**879**	**1,188**	**99.7%**
50	**267**	**912**	**912**	**1,179**	**100%**
50	267	**866**	**911**	**1,178**	**99.9%**
50	267	**821**	**910**	**1,177**	**99.8%**
50	267	**803**	**910**	**1,177**	**99.7%**
15	**218**	**946**	**946**	**1,164**	**100%**
15	218	**899**	**945**	**1,163**	**99.9%**
15	218	**851**	**944**	**1,162**	**99.8%**
15	218	**832**	**943**	**1,161**	**99.7%**

FIGURE 5. Wet steam can have varying levels of latent heat provided to equipment. Steam that has experienced 98% moisture separation nears true saturation quality

FIGURE 6. High-velocity cyclone separators can remove 98% wetness from steam provided that the flow velocity and wetness percentage are within the separator's required operating specifications

percentage of wetness — up to a 15% wet steam mixture. Some applications may have a wet steam slurry of 30% condensate, so 15% wet steam is a real possibility to be considered, particularly at the "wet end" of a plant.

The brown line represents the total heat of steam, and the two lighter lines directly beneath it show how the total heat changes when steam is wet. Heat added above the brown line shows a superheat region [*6*]. While total heat is required to produce steam, only latent heat is used in most steam-equipment applications.

Is letdown steam saturated?

A common belief is that letting down steam from a higher pressure to a lower pressure through valves can create saturated or even superheated steam. While relatively easy to demonstrate from a theoretical standpoint, such calculations may be unrealistic. Consider the two tables shown as Figure 5. The table on the left lists the total heat of steam at 200 psig for 5, 10 and 12% wetness (95, 90 and 88% dryness), as well as the required total heat for saturated steam at 15 psig. Even the 200 psig steam with only 5% wetness (1,158 Btu) is not sufficient to create saturated steam at 15 psig (1,164 Btu). In real applications, steam can have much more wetness due to poor trapping that does not remove sufficient disentrained water, insulation inefficiency and other heat-robbing aspects that naturally occur in pipe systems, such as flanges acting as a heat sink or normal convection. This is why plant steam — if not superheated — is wet.

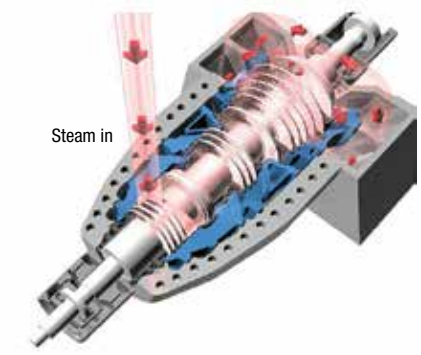

FIGURE 7. Steam turbines are crucial to plant operations

How to improve steam quality

The right-hand chart of Figure 5 shows the effects of 98% moisture separation from a steam flow with entrained moisture. All of the steam quality values exiting the separation stage approach dry steam territory, with estimated values of 99.7 to 99.9% dryness.

There are several key requirements to achieve high dryness, such as proper trapping, high percentage of "good" condition steam traps, and operation within a separator's specified required range for flow, velocity and pressure. However, when properly designed and installed, separation can significantly enhance equipment operational reliability. It is important to understand that moisture removal does not increase energy efficiency, but rather improves heat transfer and equipment reliability.

The final dryness of steam, after moisture removal, can be calculated using Equation (2):

$$D_e = D_o/[1 - S(1 - D_o)] \quad (2)$$

Where:

D_e = Steam dryness after separation, %

D_o = Steam dryness before separation, %

S = Moisture separation, %

Mechanical separation

Collecting legs and their steam traps remove condensate that has already been disentrained from flowing steam. A useful way to remove condensate that is still entrained in steam flow is to install mechanical separation. There are four key characteristics of separator design: physical impediments, impingement, flow velocity and directional changes.

Physical impediments can consist of ridges, walls or baffles. Impingement may be aided by including rough surfaces, flow velocity can be increased by pushing steam through small openings and incorporating a cyclonic design, and directional changes should twist and ideally reverse the flow path [*7*].

An example of a high-velocity steam separator incorporating these four characteristics and their interactions to accomplish efficient separation is shown in Figure 6.

Some important considerations when selecting separators and achieving the separation efficiency include the steam flowrate, its velocity — to make sure the flow stays within the required range for the separator to perform to specifications, the expected condensate load to be discharged (for the purpose of selecting the steam trap to drain the condensate), and the maximum pressure drop allowed. Selecting a separator with minimal pressure drop is especially important to maintain steam pressure and its corresponding temperature. Lowering temperature unnecessarily can de-

FIGURE 8. Steam blow in turbine areas can be avoided when using improved steam quality

crease the amount of heat that flows into certain processes, so it is key to minimize pressure drop through separators to maintain the highest temperature that can drive heat into a process.

The importance of separators

Once systems have condensate properly drained through steam traps, the use of separators can have a profoundly positive impact on various equipment.

Turbines. Turbines may be single or multi-stage (Figure 7). Regardless of the number of stages, it is important to use steam that is free from water slugs or droplets. Often, the steam quality driving turbines is less than ideal, with the result that plant operations may open bypasses or bleed valves, creating a fog zone (Figure 8). Even when such measures are implemented, turbines can experience issues with the trip and throttle valves, plating, erosion, or severe damage to the blades.

Problems caused by condensate generally fall into the following two cause classifications:

1. The condensate in the steam line feeding the turbine was not properly drained through properly functioning steam traps [*8, 9*]. This can be mitigated by implementing procedures to maintain the traps on the distribution line supplying steam to the turbine, and checking the overall drainage design to make sure that locations in which pool water before, at, or after the turbine have steam traps installed that function well.
2. The supply steam has significant amounts of entrained moisture. Not only does water striking a blade at high velocity create erosion, but there is also the dynamic that the blade spins at high speed. As steam is slung outward, the acceleration creates a drop in localized static pressure — causing entrained water droplets to vaporize. This action creates "moisture loss" (negative work [*10*]), adds to erosion, and any precipitate in the condensate will drop out of the steam and can deposit on the blades. Mechanical separation offers an excellent means to reduce or remove entrained moisture in the steam supply. Turbines experiencing frequent washdowns should have the steam trapping and steam separation systems checked for good design and operation to mitigate the frequency.

Furthermore, "The results of many tests indicate that the efficiency of a [turbine] stage is reduced by about 1% for each 1% of moisture present in the steam" [*10*].

This does not imply an energy efficiency benefit, as the same amount of energy must still be created at the boiler. However, moisture droplets that can cause interruptions from drag or flashing are removed, allowing the turbine to operate at optimal efficiency.

When the steam distribution line feeding the turbine is properly drained, and when steam is pulled

FIGURE 9. A turbine installation with properly drained and separated steam supply promotes reliable operation

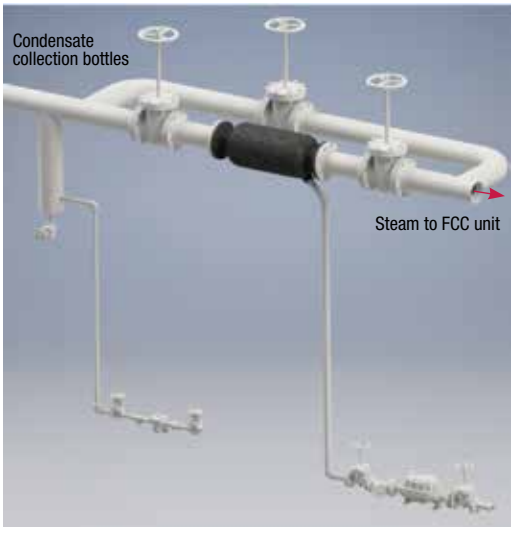

FIGURE 10. Poor quality steam to an FCC unit may require extraordinary measures

from the top of the distribution line, then a combination drainage and separation design may resemble the example shown in Figure 9. Note that after the initial separation, the trip and throttle valve is drained, as well as the turbine casing(s), and outlet riser.

Sufficient collecting legs and their steam traps do not always exist in the distribution line supplying steam to the turbine. This can create major issues in operating units, such as a fluid catalytic cracker (FCC). An oversized collecting leg (condensate collection bottle or CCB) and steam trap installation may provide some slug mitigation, which should be followed by a high-velocity mechanical separator to remove entrained moisture (Figure 10) [*9*].

Seal steam Per API 682 Plan 62. Seal steam maintains pressure on the pump seal while providing cooling to it, but wet steam can cause premature seal failure. So, moisture should not be allowed to enter and should be removed beforehand. API 682 Plan 62 is intended to prevent water in the seal, but it is commonly misunderstood, with incorrect installation as the result. An important consideration is to make sure that the seal steam supply is trapped prior to the pressure regulating valve and that the trap does not discharge condensate into the seal itself (Figure 12). Normally, seal steam lines have small diameter, but if wet steam is being supplied to multiple pumps in a compact area — the installation of a separator before branching off to the individual pumps can disentrain condensate and optimize steam quality.

Flares. Flares can experience a myriad of issues, some of which are shown in Figure 12. The cause of each issue can usually be identified as either water slugs or entrained moisture in the steam supply. Again, the mitigation efforts are the same: drain condensate from the distribution line to the flare control valve station (and after), and separate wetness out of the steam supply prior to the control valve station (and steam meter) (Figure 13).

The same basic recommendations can be made for all steam control-valve stations because steam traveling through the valve trim can reach incredibly high velocity. It is important to remove condensate and separate wetness out before the valve. Otherwise, moisture can erode the valve and vaporize during the pressure drop through the valve — causing cavitation, premature wear, and loss of control.

Ejectors and vacuum systems. The situation regarding steam quality is similar for ejectors used in vapor removal and column vacuum systems. High-velocity steam travels through the ejector at speeds of 3,000–4,000 ft/s [*11*], and entrained wetness creates severe erosion of the nozzle, diffuser and outlet elbow. "If moisture is present in the steam, a separator and steam trap should be used to improve steam quality to better than 99.5%" [*12, 13*]. Additionally, if an ejector nozzle or diffuser throat is enlarged by just 7%, the vacuum can be diminished, erratic, or broken, and the discharge temperature lowered — requiring re-

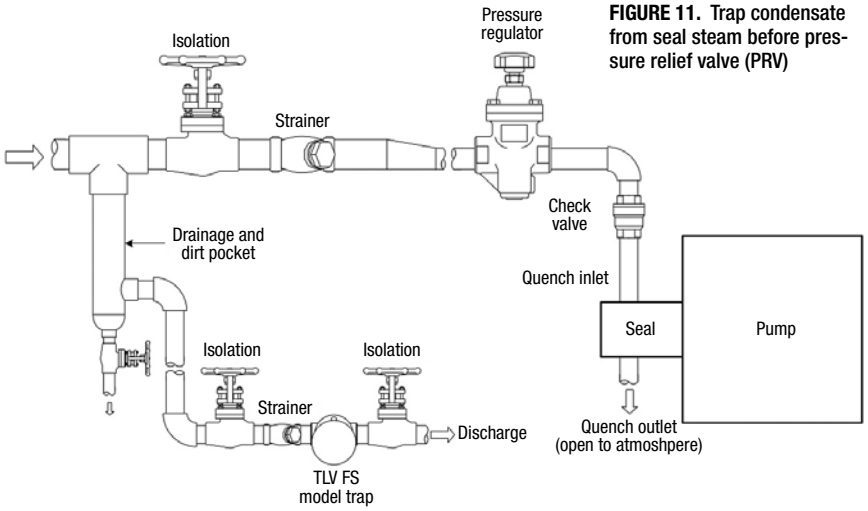

FIGURE 11. Trap condensate from seal steam before pressure relief valve (PRV)

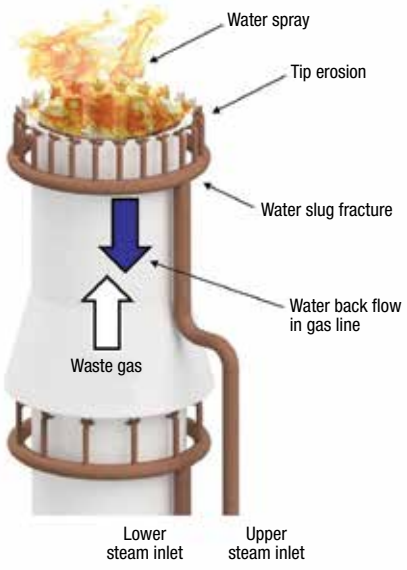

FIGURE 12. Multiple flare issues can be mitigated through proper drainage and operation

FIGURE 13. Proper design promotes control-valve reliability

placement of the enlarged component [*14*]. A solution is to make sure the steam supply array to any vacuum system or ejector is insulated, has condensate properly drained, and wetness separated (Figure 14).

Waste-heat boilers and flash-recovery systems. Heating with saturated steam conveys more uniform heat and provides the shortest heating time. This is a key consideration not only for boiler-generated wet steam, but also for steam that is produced or recovered from waste heat boilers/generators, knock-out drums, or flash recovery systems. The steam quality from this type equipment can have exceptional

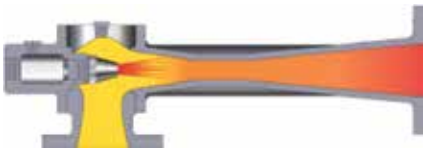

FIGURE 14. Separation promotes high-vacuum reliability

wetness that should be separated either at the point of production, or prior to the first use station (Figure 15) [*15*].

Desuperheating steam. A desuperheating system is designed so that moisture added to superheated steam lowers the temperature to 10 or 15 degrees above saturation for the delivered steam pressure. However, its temperature sensor may be located in the top of the piping — unable to determine if the valve is discharging too much water, which flows along the bottom of the piping. Additionally, the sensor may be only a few feet away from the desuperheating valve — which can lead to erroneous readings with high velocity steam flow. As a result, it is not uncommon that the desuperheating flow creates water slugs — which can be removed by steam traps and separators for optimal downstream heating and equipment performance.

Cascading condensate-to-steam systems. When designers discharge condensate from a high-pressure steam line into the next lower steam pressure, this has the detrimental effect of increasing the burden on the steam traps to handle larger amounts of disentrained condensate. Additionally, some of that high-pressure condensate mixes with the lower pressure steam flow — thereby increasing the wetness of the already wet steam. In such systems, mechanical separation can facilitate improved equipment heating, overall performance and reliability.

Final remarks

Plant steam is wet, and its suboptimal quality adversely affects reliable production and efficiency in multiple areas. It is not possible to optimize production with suboptimal steam quality, but fortunately it can be relatively easy to improve this important heat asset.

Plants should establish a maintenance priority based on the realization that steam traps play an essential role in the quality of heat used in the production process. If steam trap health is ignored or handled on a reactive basis, the steam system may not have condensate drained properly, and this can lead to water hammer issues, as well as erosion and catastrophic damage to equipment. It also increases wetness in the steam supply, which in turn hinders process heating operations. Additionally, determine which heating equipment, turbines, and vacuum ejector systems can be enhanced by using mechanical separators to disentrain moisture from wet steam, thereby bringing its quality to near saturated levels.

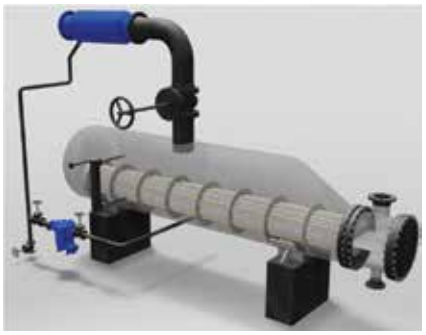

FIGURE 15. Waste-heat boilers, steam generators and flash-recovery installations are examples of high-wetness equipment that can benefit by using steam separators

Owners investing in capital projects may want to pay close attention to the design of new systems to ensure that appropriate drainage and separation equipment are included. Often it is difficult, if not relatively impossible, to correct a steam system once it is operating with lesser quality steam — with the unfortunate result that expected benchmark operation cannot be achieved. Your steam is wet, but it does not need to remain suboptimal if you implement suitable measures to improve its quality. ■

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Industry Mentors: An Integral Part of Education

An experienced engineer who mentors young engineers and a student mentee share their perspectives

Carl N. Rentschler and Peter Capitano

Mentors provide critical support and guidance to students pursuing an engineering education, and complement coursework aimed at readying a new engineer for the workforce. Mentorships can be provided by faculty, peers or industry volunteers. This article focuses on industry mentors who have the ability to offer varied life experiences in the workplace. This background is unique compared to other mentorships, because it is often public-facing and generally involves experience from a variety of positions. In the current and recent business climate, industry mentors often faced job changes through their careers, and these provide experiences of interest to students. This article provides perspectives by both a long-time industry mentor and a student being mentored. The cross-section of perspectives provides a thorough assessment of industry mentorships.

Achieving an engineering degree and preparing for a professional career can be daunting, and helpful guidance from an experienced engineer can be of significant value (Figure 1). Industry mentors can provide constructive input based on years of front-line experience in the engineering profession. Establishing a mentor/mentee relationship provides benefits for both sides and ultimately provides the guidance needed by a student to embark on a focused career. A mentorship takes effort on both sides, and the results are often in direct proportion to time invested. Students are urged to consider a mentor as part of their educational process, and long-term engineers are encouraged to volunteer to guide students. The result will be positive for both parties and can lead to long-term relationships that are mutually beneficial.

FIGURE 1. Achieving an engineering degree and preparing for a professional career can be daunting, and helpful guidance from an experienced engineer can be of significant value

Mentor perspective

Highly experienced engineers and engineers in the twilight of their careers have extensive life and professional experiences that were developed through the highs and lows of various positions. This background can be helpful to young engineers who are about to start their careers. Many seasoned engineers, or those already retired, feel a calling to "give back" to others. Mentoring offers a perfect opportunity to satisfy internal interests in helping others, and fills a need for new engineers to gain guiding input as they embark on their careers.

As experienced engineers approach the end of their careers, it is important to have meaningful activities as a basis for continued stimulation and learning. This provides professional growth, even while an individual's primary career is slowing down. Mentorships provide this opportunity for continued growth. Not only is there significant satisfaction in serving as a mentor, but there is the likelihood that there will be learning from the mentees. Students can share their experiences and relate the latest engineering techniques, which are generally focused in the automation areas. This leads to a two-way interchange of ideas, and it enhances the mentorship process.

Mentors have undoubtedly developed a substantial network of professionals through their years of work. As discussed in previous articles [*1, 2*], this has never been more important as the business world cycles up and down. Many mentors started their careers with the idea that they would retire from the company that first hired them. This is unheard of now, and the likelihood of staying with one company for an entire career is very remote. Networks are very important in moving through a career, and even landing that first position. The industry mentor will be quite helpful in guiding a student on a path that requires a growing network.

Mentee viewpoint

As the mentee co-author of this article, I would like to describe a stu-

dent's perspective of collaborating with an industry mentor. Through programs offered by universities around the country and world, students who sign up for a mentoring program can be paired up with alumni or other professionals who had experiences similar to their own ambitions. After a match-making process handled by the school is completed, students will find out who their mentor is and then the process of connecting begins. If properly taken advantage of by the student mentee, the mentorship can be a rewarding experience for both parties.

Most college-age students who reach out for a mentoring program will do so because they have limited background in their chosen field and want access to someone who does. The typical mentor available to the students would be a person who has a breadth of knowledge in their field and wants to pass it down to the younger generation. After years of experience, their credentials provide sufficient background for the student to take their advice seriously. It is reassuring for the student to know that if they do have any questions about situations they encounter, chances are the mentor has already seen it and will know how to deal with it properly.

Not only has the mentor dealt with industry-related issues that could arise, but they also have vast experience in making decisions for their own personal career path. In the decision-making process for finding an internship, being able to have access to someone who has already had to make these decisions for themselves is very helpful. This advice will not only be available for career opportunities that arise during school, but for many years to come after one finishes their education. Such guidance could be invaluable for a young person's career as they progress and have harder choices to make.

FIGURE 2. In communicating with a mentor, the mentee gains experience in communicating with a professional colleague

Most people in college have very little to no experience communicating in a professional setting due to the limitations of opportunities for younger people. For example, while working in early jobs in the service fields, effective communication is not of the utmost importance. In communicating with a mentor, the mentee gains experience in communicating with a professional colleague (Figure 2). Being able to perfect the ability to craft clear and concise messages in a casual setting will enhance the mentee's ability to do so in a more professional setting long-term.

Going forward for the mentee, knowing that they have the mentor's support and guidance is very comforting. Whether issues arise in academic, professional or on-site areas, knowing that their mentor will have reliable advice for how they should be dealt with is reassuring for the mentee. For a lot of young people there is a sense of worry that comes with the uncertainty of the future. However, with the help of a mentor, young people will be able to deal with issues that arise with confidence as opposed to tentativeness.

One of the most important attributes for having long-term success is having a dependable and diverse network and any kind of insight that is different to their own. That being said, knowing the benefits of having a mentor makes it an easy decision to take advantage of this "free" learning and support experience.

FIGURE 3. Mentors have vast experience in making decisions for their own personal career path, which can be helpful to young engineers who are in the decision-making process for finding an internship, as well as for advice about future career opportunities

Making the mentorship work

Mentorships require effort on both sides to be effective, and this should be a point of focus from the outset by both the mentor and student. Mentor assignments are often made on an arbitrary basis as an interested student is paired with a mentor. The relationship has the best chance of working and being effective if there are common interests between both parties. The primary area of focus should be commonality in technical interests. For example, a student with interest in structural design may not align with a mentor who has a focus in the environmental area. Common personal interests, such as sports, for example, are also beneficial in establishing alignment. It is perfectly acceptable for either party to suggest a "breakup" if alignment is missing. It will eventually be unproductive and a struggle for both mentor and mentee if the two parties are not meshing, and early on is a good time to seek a new mentor/mentee relationship.

Generations. Generational differences must be considered in making a mentorship effective and workable. More than likely, most mentors are from the Baby Boomer generation. It has been well documented that this generation sees the workplace differently than Millennials or Generation Z. The Baby Boomer generation places more focus on working and often find its worth in a solid work ethic. Later generations, on the other hand, place more focus on work-life balance and may not subscribe to a mentor promoting a strong work focus. As an example, the mentor co-author of this article tried to guide a mentee to what he thought was a great opportunity with a superb company, even though it was at a location requiring relocation. The student, on the other hand, was more focused on location and considered the job secondary. Such a difference in viewing the landscape requires understanding and open discussions by both parties, but can be viewed as positive, since varied viewpoints are considered.

Trust. More than anything, it is important to develop a level of trust between mentor and mentee. There is no special formula for this, except to have an open mind to the viewpoints on both sides, and a respect for differences of opinion. The process is best started by the mentee outlining his or her goals. The mentor can then springboard off these goals in planning his or her guidance. The process is two-way between mentor and student as both share knowledge and ideas, with the goal of bridging the gap between academics and the professional world. Hopefully this exchange, openness and trust will result in the student finding a successful path into a rewarding job.

Communication. There are numerous forms of communication between mentor and mentee, including phone, email, video and personal meetings. The best approach is likely to use all of these forms depending on circumstances. Both parties are often busy, so email and phone are appropriate during these times. When time and logistics permit, it is worthwhile to have face-to-face meetings. It may also be possible to attend a common activity together, such as a seminar. More than anything, it is important to maintain open and continued communications, but not to the point of being bothersome for either party. It is quite common for mentor and mentee to develop friendships that are maintained well into the mentee's career.

Limits. Finally, it is important to have an understanding of the limits of a mentor. The advice provided by a mentor serves as guidance or a sounding board, but not the main crutch of a student. The mentee is still responsible for determining his or her path forward. Also, the mentee should not have unrealistic expectations of the mentor. The mentor co-author of this article has experience in which he was teamed as a mentor with foreign nationals, and they had an expectation that he would find them jobs that would prolong their time in the U.S. When it was conveyed that this is not a realistic expectation, the mentees ended communications. It is certainly reasonable for a student to request resume review and guidance, career options and constructive feedback, but laying out the mentee's job path should not be expected. ■

Edited by Dorothy Lozowski

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Peter Capitano is a senior in college, currently studying civil engineering at Penn State University. In May 2020, he will be graduating and starting a full-time job at a medium-sized company.

Gulf Coast

special advertising section

CHEMICAL ENGINEERING

Access Intelligence

Inside:

Smart actuator optimizes control valve performance

The new Smart Electric Valve Actuator (SEVA) from Badger Meter stands up to extreme conditions while providing exceptional position accuracy

Since 1905, **Badger Meter** has been recognized as a leader in the development and manufacture of flow management solutions. The company has introduced the latest generation of its Smart Electric Valve Actuator (SEVA) solution, which now offers Modbus RTU, Modbus TCP/IP and SoloCUE® connectivity.

SoloCUE connectivity

SoloCUE is a software solution that provides easy access to the setup of both the feature-rich SEVA and its protocols. This custom-built, bulletproof platform allows end-users to visualize SEVA's performance and setup characteristics.

Product design

SEVA employs cutting-edge technology and delivers exceptional accuracy and repeatability. Designed for extreme conditions, the actuator has military-grade components.

SEVA has 100-lb. and 200-lb. thrust models. There are several options available for communication protocols, including Modbus RTU, Modbus TCP/IP and the Industrial Ethernet Protocol (EtherNet/IP). It is is certified by FM, EX, CSA and CE. The actuator allows for both linear and Device Level Ring (DLR) ring network topologies.

Position accuracy

SEVA provides an exceptional level of position accuracy (±1% of full scale) with five available positions when there is a loss of power. The device also features four positions when there is a loss of signal. Both the full closed and full open positions are defined during setup.

In addition, SEVA has an internally powered (active) feedback signal, which actively communicates stroke position to the control system. Its feedback sensors are crucial in more precise applications. SEVA even provides a manual override capability to help the operator in loss-of-power situations.

Other features

The SEVA assembly has the option to include two user-adjustable limit switch outputs. An external signal is provided once the set points of the limit switches are met. Furthermore, the electric actuator can split the incoming 4–20 mA signal and use either the lower or higher range of the signal for full stroke operation. A hyper terminal server makes it possible to change the type of split range.

SEVA was specifically designed to minimize the number of models needed to work with different electrical demands. Its Universal AC Input with voltage protection will work with 115 V AC, 230 V AC and 24 V DC power supplies. This feature ensures confidence that the actuator will provide a single source for different process needs. SEVA can receive analog input signals from 4–20 mA, 0–5 V DC or 0–10 V DC.

badgermeter.com/chemicalSEVA

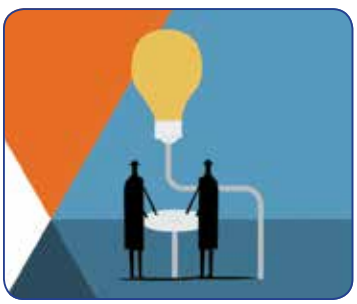
Partners in a Sustainable Plastic Revolution

How Loop's disruptive depolymerization technology is changing the plastic world

Most plastic and fiber production today is a classic example of wasteful linear economy. But in 2014, a small innovative company set out to disrupt traditional plastic and fiber manufacturing by up-cycling with waste. Starting in an improvised lab located in a garage, Loop Industries created a revolutionary low-energy depolymerization technology that transforms low value and no value waste plastic into high-value chemicals used to produce virgin-quality PET plastic for use in food-grade packaging, like the kind used to make water bottles. In addition to reducing greenhouse gas emissions and dependence on fossil fuels, Loop's technology also dramatically reduces environmental impact by diverting PET plastic and polyester fibers from oceans and landfills.

Putting the Revolution In Operation

Through its vision, Loop Industries had set in motion a sustainable plastics revolution. But as a start-up company, to ensure business success they needed to partner with a process simulation software provider that could accommodate their budget, provide expert technical support, and have the ability to scale to meet Loop's needs as it grew. After evaluating several different process simulation software companies, Loop chose **Chemstations** due to its modular customization, easy integration, flexible licensing, expert technical support and affordability.



Proving Chemistry Viability

By selecting CHEMCAD from Chemstations, Loop Industries benefitted from a suite of six modules that could be purchased individually or bundled as needed to accommodate Loop's budget and processes. Loop also received personalized guidance from multilingual support staff and high-level engineers from Chemstations who worked to ensure simulations went smoothly and that the chemistry was viable. In addition, Loop had 24/7 access to a library of training videos on the CHEMCAD customer portal. During the simulation process, Loop used the operating settings based on the CHEMCAD CC-BATCH module simulation results to run the three different distillation stages of Methanol Recovery, Water Removal, and MEG Purification. Based on the successful pilot results, Loop created initial documentation around its technology that confirmed its viability to the market.

Driving Productivity and Growth

With the software simulation and proactive technical support provided by Chemstations, Loop has created a truly circular supply chain for one of the world's most widely used plastics. Throughout its growth, Loop's relationship with Chemstations has also grown. Today, Loop relies on the full CHEMCAD-SUITE of products to tackle their toughest process models. For more information, visit

www.chemstations.com/loop1

Vibronic Level

Vibrating fork point level - Endress+Hauser Liquiphant FTL51B

The basic vibronic technology hasn't changed much over the years. However, today's instruments now employ technological innovations to bring them into the digital age, meet the needs of Industry 4.0 and the Industrial Internet of Things (IIoT), provide diagnostics themselves, and provide access from mobile devices.

Vibronic instruments are well suited for liquid level applications, including point detection at the top and bottom of tanks, certified leakage monitoring and overfill prevention, use in hazardous environments, and in applications requiring safety integrity level (SIL) 2 and 3 certification. These instruments can be used in storage tanks, containers, and pipes for point level detection of all types of liquids.

Some advantages of vibronic instruments include:

- Unaffected by media—Vibronic instruments can be used to measure the presence of liquids with viscosities up to 10,000 mm2/s and densities greater than 0.3 g/cm3
- Unaffected by media properties—A vibronic instrument is not affected by changing flow, turbulence, gas bubbles, foam, vibration, solids content, or build-up
- Easy installation and ready for use without calibration—In most cases, a vibronic instrument works in the application without any required adjustments or calibration
- No wear and tear, maintenance-free—A vibronic instrument has no moving parts and requires no maintenance other than periodic cleaning
- Self-monitoring—New vibronic instruments are equipped with internal diagnostics and the ability to automatically perform proof tests and verification

Vibronic instruments have no moving parts, so the only physical problems they might encounter are corrosion and build-up of process materials on the tuning forks. Modern vibronic instruments have built-in diagnostics to detect corrosion and build-up by monitoring the frequency of the tuning fork. Early detection allows plant personnel to address issues in a proactive manner prior to failure.

Process manufacturing and other industrial facilities must often provide documented evidence of level instrument performance to maintain compliance with various regulatory agencies. Typical requirements are:

- Level instruments have to be verified at regular intervals
- Verification has to be performed by a qualified third party and with an accepted inspection method based on quality regulations such as ISO 9001
- A test report needs to be provided for documented proof of verification

Today, level instruments must conform to various safety regulations, diagnose themselves, perform self-testing, and provide data for IIoT and other digital initiatives. Modern vibronic instruments are up to the task, continuing to provide reliable operation for level detection, with added functionality to meet current and future demands. **www.us.endress.com**

Novel Filtration Design Delivers Plant Operations Success

FTC provides 176% more effective surface area and fewer changeouts with Invicta filters and vessels

FTC's Invicta filters and vessels offer maximum filtration performance and online life while minimizing OPEX and CAPEX.

The Invicta cartridge filter and vessel system from **FTC** represents reliable, high efficiency liquid-solids filtration with immediate cost savings for plant operations. Invicta's coreless, trapezoidal filter design delivers up to 2.76 times the effective surface area of cylindrical filters within a given vessel footprint. The Invicta vessel design allows for more filter elements and less unused "dead" space within each vessel. Together, the system delivers absolute-rated filtration and the lowest cost of ownership available today.

Operators understand the high cost of inefficient filtration. They recognize that low efficiency filtration units and undersized filtration systems both lead to frequent and prolonged process upsets, costly filter changeouts, and higher process-related operating costs. Additionally, frequent filter changeouts result in higher direct consumable costs as well as indirect costs related to safety, labor, inventory, and disposal.

Traditional (cylindrical) filter designs waste precious space in filter vessels, especially when multiple filters are placed in a housing. In contrast, Invicta's innovative design delivers significantly improved element packing density and a longer online life. Longer online life means there are fewer filters to stock, fewer filters to change, fewer filters to dispose of, lower direct and indirect filtration costs, and reduced operator exposure to hazardous process streams.

The Invicta filter and vessel system offers:

- Lowest cost of ownership on the market
- Unmatched effective filter media surface area
- High vessel solids loading capacity
- Absolute rated 99.98% efficiency
- Lower pressure-drop across the vessel
- Improved process reliability
- Fast and easy installation
- Compact storage and disposal
- Rapid vessel upgrades or new Invicta vessels

Invicta cartridges are offered with a broad range of end cap and media options to satisfy most chemical and thermal compatibility needs. Invicta vessels are available in either horizontal or vertical configurations to accommodate space restrictions and customer preference, and FTC maintains a fleet of Invicta vessels immediately available for sale or rent. Common applications for Invicta include water and wastewater, process fluids, hydrocarbons, brines, solvents, amines, glycols, fuels, chemicals, acids, and bases.

Contact FTC today to find out more about Invicta and what it can do for your process stream. **www.ftc-houston.com**

Optimizing crude oil distillation equipment: Sulzer's separation technology supports even the most ambitious refining process intensification projects

To remain competitive, businesses in the oil and gas sector should invest in technologies that can help them improve processing performance while reducing production costs. Choosing a reliable partner for cutting-edge mass transfer components, such as Sulzer Chemtech, can help to significantly boost refining operations.

Sulzer supports oil and gas companies in the downstream sector by designing, manufacturing and installing high-performing, state-of-the-art separation systems. The company's comprehensive range of technologies increases equipment's service life, column capacity and separation quality by tackling the biggest operational issues in refineries. These include foam formation, fouling caused by salt deposition or sand/catalyst particles, corrosion and coke formation.

One of the most common issues in preflash columns is foaming. Refineries can rely on Sulzer's innovative solutions, such as an Inlet Cyclone or GIRZ, to mechanically control and break foam as it forms without the use of chemicals. These cyclones are positioned on the column inlet and utilize centrifugal force as well as the momentum of the feed stream to separate its phases. As a result, the gaseous phase is released from the top, while liquids accumulate at the bottom of the device. This in turn reduces production costs and maintenance activities while improving product purity.

The Inlet Cyclone also plays a role in preventing fouling and corrosion of the column. When combined with Sulzer's specialized column trays and valves, refineries can further minimize these issues as well as reduce coke settling. For example, special anti-fouling valve trays, such as the VG AF, have excellent fouling resistance, increasing the overall system reliability, while improving the column performance.

As a full-service provider, Sulzer offers a wide range of dedicated engineering services that can help refineries and petrochemical complexes to optimize their processing activities and increase plant productivity.

www.sulzer.com/en/applications/oil-gas-chemicals/downstream/refining

Measuring PVC Level In Silos

Measurement Objectives:

- ✓ Reliable production supply thanks to continuous inventory level monitoring
- ✓ Reliable long range measurement even with extremely low tank levels in narrow silos
- ✓ No need for instrument flushing systems despite presence of products that are extremely sticky and dusty

Background:

A company that manufactures and processes PVC stores a variety of product shapes in several slim silos reaching heights of more than 65 feet (20 m). They supply the product for their own production as well as to third-party producers. In addition to PVC powder and PVC granulate some regenerated PVC that is extracted from old shredded products is also stored.

The level in the silos must be continuously measured to ensure a reliable production supply. The atmosphere in the silos is extremely dusty and the PVC dust is very sticky. The customer was interested in a type of non-contact radar measurement that did not require any kind of antenna cleaning since there is no compressed air supply.

A **KROHNE** OPTIWAVE 6500C 80 GHz FMCW radar level measurement instrument with a 3 inch (80mm) lens antenna specifically designed for solid applications is ideal for use in these applications.

FMCW stands for "Frequency Modulated Continuous Wave" and is one of two popular radar level measurement techniques. When compared to the pulse method, FMCW features a much wider dynamic range and better signal strength. Those advantages clearly

benefit these types of challenging solids and powder applications as well as many difficult process liquid level and reactor vessel applications.

The unique lens antenna is especially beneficial in powder applications since it is self cleaning, and it focuses the available signal much more than a horn can which also improves performance in tall, narrow vessels.

This solution allows the company to monitor the level in the silos at any time. It also eliminates any chance of running on empty which would put the production processes at risk.

KROHNE has several process level solutions for all types of solids or liquid applications including FMCW radar, ultrasonic and mechanical technologies. If you have a challenge with level, please contact us to evaluate it and suggest some possible solution.

us.krohne.com

The Experts In Pollution Control Equipment

CR Clean Air has been providing custom engineered pollution control solutions to the CPI for over sixty years.

When it comes to your plant, you cannot afford downtime. Today having a comprehensive emission control program is more important than ever. Not only does it ensure the safety of your employees, it keeps the state out of your business. Systems installed in the 1990's when the Clean Air Act was last overhauled are probably not the Best Available Control Technology (BACT) today and let's face it - your process have probably changed over the years, not to mention expanded. When was the last time you even gave your pollution abatement equipment a second thought? Why wait until a permit is about to expire?

To make sure that your plant can operate at peak performance, why not call the experts today? The engineers at **CR Clean Air** have the experience to customize a wet scrubber fit for your plants needs. From acid gases such as HCL, to Ethylene Oxide to NOx and SOx emissions, if it can be scrubbed, we have probably scrubbed it. Our range of offerings, from jet venturis to packed towers, are available as standalone items, or can be supplied with peripheral equipment including liquid recirculation pumps and (when needed) exhaust blowers with or without a discharge stack. We also can provide instrumentation and control packages, from the simple to the complex.

With CR Clean Air, our team will work with your entire team, from the process engineers to the plant operators to ensure that all equipment is to spec. With materials ranging from FRP to Stainless Steel to High Grade Alloys, we can meet almost any challenge. Be you the owner / operator or an EPC working on a procurement package for a key client, we deal with companies of all sizes across a wide range of industries. We have many successful installations across the gulf coast over the years, and are proud of each and every system we have commissioned.

Remember – when it has to work the first time and every time, go with the leaders in pollution control technology.

www.crcleanair.com

A classic mixing tool for the petroleum industry

Ross LPD Static Mixers are rugged, reliable devices that combine excellent inline mixing with minimal pressure loss

Ross Low Pressure Drop (LPD) Static Mixers are used throughout the oil and gas industry for turbulent-flow mixing applications.

Shown are removable LPD mixing elements supplied with retainer ring and flanged housing.

These heavy-duty low-maintenance devices serve in continuous operations where high performance and accuracy are required, such as on-line water determination of crude oil; dosing of various additives into gasoline; blending different kinds of fuel oils; gas-gas blending; and pipeline reactions, among others.

Static mixers have no moving parts and the energy for mixing is available in the form of pressure. Pressure loss – a natural consequence of static mixing – sometimes becomes the deciding factor in mixer selection. The LPD Static Mixer remains a classic choice for many inline blending requirements due to its simple and durable design capable of uniform mixing with little pressure loss. The mixer elements consist of semi-elliptical plates carefully positioned in series to split and rotate the product 90 deg. in alternating clockwise and counterclockwise directions.

LPD mixers in diameters from 1 in. through 2.5 in. are welded to a central rod, while larger elements are welded to four outside support rods for maximum rigidity and stability. Units as large as 48 in. diameter can be supplied as stand-alone mixer elements or as modules complete with a mixer housing and injection ports.

Established in 1842, Ross is one of the oldest and largest mixing equipment companies in the world. Ross mixing, blending, drying and dispersion equipment is used throughout many industries in the manufacture of foods, adhesives, electronics, coatings, cosmetics, pharmaceuticals, plastics and composites.

www.staticmixers.com

Saint-Gobain NorPro Provides Full Line of High-Quality Denstone® Support Media to Customers Worldwide

Denstone® Support Media. Reliability Delivered.

Figure 1: Denstone® support media fits a wide range of fixed bed reactor applications.

Saint-Gobain NorPro introduced Denstone® catalyst bed support media for fixed catalyst bed applications more than 70 years ago. Today, their extensive range of bed support media includes Denstone 57, 2000, 99 and Denstone deltaP shaped media. This full line of support media provides consistent, worry-free support for catalysts of all sizes and materials.

Denstone 57 spherical support media is Saint-Gobain NorPro's flagship product. It has remained an industry standard for over 70 years, providing consistent and unparalleled reliability as a support media for numerous industrial applications.

Denstone 2000, a ceramic support media with an engineered microstructure, offers increased survivability after thermal cycling and rapid depressurization as experienced in severe hydroprocessing applications.

Denstone 99 is a high-purity alumina support media for high temperature, steam, ammonia processing and other petrochemical applications where silica leaching is a problem.

Saint-Gobain NorPro is the only supplier producing innovative shaped ceramic support media. Denstone deltaP shaped media is available in three sizes: P1, P1.4 and P2. Its unique structure enables an upper support layer with a typical diameter of 11.5 mm to effectively retain a bed of 1.6 mm catalyst without any migration into the support layer. This eliminates the need for micro-sized support media, reduces the number of support layers needed, reduces pressure drop and increases the space available for catalyst or adsorbent capacity in the process reactor.

With regional manufacturing facilities and teams located in the Americas, Europe and Asia, Saint-Gobain NorPro provides security of supply unmatched by single location competitors, enabling quicker response and delivery if one plant is in turnaround mode and timely product delivery is critical.

Each location adheres to ISO-certified processes for their regions' requirements as well as rigorous and comprehensive in-house standardized qualification test methods prior to shipment. These tight engineering controls ensure that every single batch of Saint-Gobain NorPro's ceramic support media maintains the consistency and reliability that the Denstone brand of support media has become synonymous with.

For more information about Denstone support media visit **www.denstone.com**

Keeping Turnarounds on Track with a Reliable Plugging Solution

Pop-A-Plug® Tube Plugs from Curtiss-Wright EST Group

Pop-A-Plug Tube Plugs maintain a leak-tight seal without causing damage to tubes or tube sheets

Many turnarounds may be scheduled months in advance, yet plants still struggle to meet start-up and completion dates. By some industry estimates, up to 90% of turnaround projects extend beyond their scheduled time. Delays of even a few days can add millions of dollars to the cost of a turnaround when factoring in reduced productivity of the facility and additional on-site contractor labor.

For over 50 years, **Curtiss-Wright's EST Group** have been designing and manufacturing products and systems to simplify maintenance to shorten turnaround times for operation-critical equipment, from shell-and-tube and air-cooled heat exchangers to pipelines, piping systems, and pressure vessels.

A Permanent & Cost-Effective Solution for Tube Plugging

Shell-and-tube heat exchangers represent one of the most common and critical pieces of process equipment in plants. In most environments, heat exchanger tubes eventually degrade or leak as a result of prolonged runs, impurity-induced fouling, and corrosive fluids that run through the system.

One traditional process of sealing tubes involves installing tapered plugs, often welded into the tubes with pre-heat and post-weld heat treatments. This process is both time-consuming and unreliable. Tubes and tube sheets may suffer from circumferential cracking after units are brought back into service from pressure and temperature cycles that are common during normal operation. Curtiss-Wright EST Group's heat exchanger plugging system greatly minimizes delays in equipment maintenance during turnarounds by eliminating welding altogether.

The system includes **G-160 Tube Testing Tools** for leak detection in shell-and-tube heat exchanger, boiler, and condenser tubes. These tube testers can rapidly pinpoint tube leaks while providing a safer environment for plant personnel with their patented gripper technology.

Once leaks are identified, **Pop-A-Plug Tube Plugs** deliver a permanent and cost-effective plugging solution. Plugs install hydraulically using a unique breakaway, eliminating the labor and time associated with welding tapered plugs into place. Installed properly, Pop-A-Plug Tube Plugs maintain a helium leak-tight seal without causing damage to tubes or tube sheets. They can withstand extreme thermal and pressure cycling at working pressures up to 7,000 PsiG (483 BarG), and meet ASME PCC-2 (Article 3.12) recommendations for the inspection and repair of shell and tube heat exchangers.

Pop-A-Plug Tube Plugs are available in wide range of materials, including corrosion-resistant alloys, matched to the metallurgy of the unit in which they are to be installed. Matching plug and tube material mitigates thermal expansion/contraction issues, and undesirable galvanic corrosion, ensuring the leak tight seal.

Curtiss-Wright EST Group serves a global customer base with an extensive inventory ready to ship, and 24/7 emergency manufacturing available. For more information, visit **www.cw-estgroup.com**

Gas Composition Matters for Flow Meter Accuracy

Case study shows flow meters calibrated to measure "natural gas" were programmed on incorrect gas compositions leading to accuracy errors of ±10%.

Natural gas is colorless and odorless, so natural gas processors and transporters add odorant to the gas to identify leaks by smell. Odorization systems typically require independent measurements of the amount of natural gas odorized and the amount of odorant consumed. Maintaining the proper ratio of odorant to gas is essential for quality control.

The North American Energy Standards Board (NAESB) suggests composition ranges of various components in natural gas, with a typical analysis contains approximately 94.9 percent methane, 2.5 percent ethane, 1.6 percent nitrogen, and 1.0 percent other components. However, it is reported that over 10 percent ethane can be present in natural gas obtained from horizontal drilling. In contrast, significant amounts of heavier hydrocarbons may be present in natural gas from other sources. These types of differences in composition can adversely affect flow meter performance leading to accuracy errors of ±10%.

In a recent case study of a transporter in Europe, the existing flow meters were configured for the NAESB's typical composition and calibrated using the factory-standard surrogate natural gas. The composition of the actual natural gas was significantly different, it varied by site, and was likely to change over time.

The transporter wanted the ability to configure the actual composition of its natural gas in the field without returning the flow meters to the factory for calibration, all without loss of accuracy.

The manufacturer used the actual natural gas compositions to perform calculations that confirmed the flow measurement errors were like those experienced by the transporter. The traditional approach to resolve this problem would be to return the flow meters to the factory for recalibration with various surrogate gases representative of the various natural gas streams. This was not acceptable to the transporter in the short term and would have made compensating for future composition cumbersome in the long term.

Consequently, the existing flow meters were equipped with a gas selection library programmed into the flow meters' electronics. Using this technology, each component in the natural gas could be configured in 0.1-percent increments in the field to measure the flowing natural gas with no loss of accuracy.

As a result, the transporter was able to create a schedule to test for changes in gas composition. When changes were detected, the flow meters' gas selection technology was used to program the new gas composition into the electronics to maintain the highest gas flow measurement accuracy.

www.foxthermal.com

Gas	NAESB Range	Texas	Nigeria	Canada	Italy
Methane	87.0 - 96.0	93.1	86.5	85.8	85.6
Ethane	1.8 - 5.1	3.0	7.2	4.8	7.7
Nitrogen	1.3 - 5.6	0.1	0.1	4.6	3.1
Carbon Dioxide	0.1 - 1.0	2.1	0.7	2.2	1.3
Propane	0.1 - 1.5	0.8	3.5	2.3	1.7
Iso-Butane	0.01 - 0.3	0.2	0.8	0.1	0.2
Normal-Butane	0.01 - 0.3	0.24	0.67	0.15	0.30
Oxygen	0.01 - 0.1	0.00	0.00	0.00	0.00
Iso-Pentane	Trace - 0.14	0.12	0.23	0.01	0.12
Normal-Pentane	Trace - 0.14	0.08	0.15	0.01	0.06
Hexanes Plus	Trace - 0.06	0.24	0.11	0.01	0.05
H2	Trace - 0.02	0.00	0.00	0.00	0.00
% Error	N/A	+4.0	+7.9	+9.8	+10.1

Chemical Compositions of Natural Gas (in mole percent)

Leader in EHS Consulting for the Chemical Industry

Trinity Consultants helps organizations overcome complex, mission-critical challenges in environmental, health and safety (EHS), engineering, and science through its consulting, software, training, and staffing services. Supporting clients in geographies worldwide, Trinity serves a broad range of manufacturing sectors such as: Chemical, Petrochemical, Petroleum Refining, Pharmaceuticals, Pulp and Paper, and Food and Beverage.

Trinity works with the chemical process industries to assess and implement practical solutions for obtaining environmental permits and managing environmental compliance. Its consultants assist facility managers with permitting, applicability, and compliance as related to multiple regulatory programs, such as

- Clean Air Act permitting and compliance
- Clean Water Act requirements
- Waste management regulations
- Noise and odor issues
- Industrial hygiene and safety management
- Process safety management

Within the complex air quality requirements, Trinity assists with applicability and compliance for chemical sector clients including, but not limited to:

- NSPS regulations
- 40 CFR 61 (e.g., BWON, J/V, BB)
- 40 CFR 63 (e.g., Refinery MACT I & II, HON, MON, Coatings MACT, Pharma MACT, CMAS Rule, HCl MACT, PAI, MACT YY)

Trinity assists with day-to-day compliance activities by developing compliance tools that detail the elements required to demonstrate compliance with environmental regulations.

Sustainability & Environmental Management

In addition to regulatory-based support, Trinity advises chemical clients on managing carbon/energy risk to facilitate cost-effective business decisions and on proactively addressing stakeholder concerns regarding the EHS aspects of sustainability.

For more information, call 800-229-6655 or visit **www.trinityconsultants.com**

LDAR Capabilities

Trinity has provided Leak Detection and Repair (LDAR) assistance with a level of excellence and responsiveness that many clients return to Trinity when faced with additional air quality challenges. Trinity has extensive LDAR knowledge and regulatory compliance expertise through direct experience at many facilities subject to the array of LDAR regulations including NSPS, MACT, NESHAP, and RCRA. In addition to regulatory knowledge, Trinity has certified FLIR GasFinder Thermographers, enabling its consultants to assist with the identification of potential leaks as well as overall program management.

Trinity Consultants

The Important Role Service Plays in Chemical Processing

Zeeco offers expert, responsive aftermarket service and support for Zeeco and other manufacturers' equipment.

Improving up-time is always a key goal for operators, and the equipment they need to keep online only becomes more and more specialized over time. To ensure adequate up-time, companies sometimes seek to maintain specialized, highly technical personnel on staff, although it can be challenging and costly to keep suitable staff to handle the wide range of equipment in a typical facility. But when downtime happens, companies that do not have that capability are forced to second-guess their staffing decisions. Another alternative is to develop a relationship with a third-party service company that can maintain technical personnel to service this equipment.

History teaches us companies that focus on preventative maintenance tend to experience far less equipment downtime and emergency expense requirements. But how and when to undertake those types of maintenance activities has also been the topic of many discussions.

Knowing the best approach to develop an effective maintenance plan can be difficult. Do you keep it in-house or seek outside support? More companies are finding that developing third-party service alliances with equipment manufacturers like **Zeeco** is proving to be not only a safe way to operate, but also a cost effective one. Suppliers that have broad regional coverage of personnel, as well as remote-access capabilities, have proven even more valuable with the travel restrictions brought about by COVID-19 this year.

Procurement of key operational equipment can no longer be solely about price. Today, knowing a manufacturer's ability to provide aftermarket service support should play a key role in decisions. Packaging preventative maintenance in the purchase of new equipment can provide operators with the security of having the most experienced personnel for necessary maintenance available and a greater access to critical spare parts.

So, when considering the cost of downtime and technical maintenance for equipment operations, choosing the right solution is important. Some manufacturers, such as Zeeco, have experienced service staff capable of supporting not only their own, but also other manufacturers' equipment. This allows use of a third-party service company that can develop a complete service plan covering multiple facilities and a variety of equipment technologies and OEMs.

At a time when economic conditions challenge companies to find new ways to improve profitability, companies should look for manufacturers like Zeeco that provide not only efficient designs for new equipment, but also preventative, remote, and emergency service to maximize facility up-time.

www.zeeco.com

Looking for ways to step up your petrochemical and polymer production?

Fluid bed dryer/ cooler HDC for PVC

As in every application in the chemicals industry, there is no room for compromise when it comes to petrochemical and polymer production. Not just in terms of safety and product purity, but also when it comes to non-stop performance. This is why we at **ANDRITZ** are determined to constantly work on our product portfolio and develop new solutions with our customers – alongside improving proven machines and processes.

SEPARATION CHALLENGE? – RESOLVED!

Comprehensive expertise in dewatering, drying, service, and automation. The ability to tailor the most reliable technology brands in the business to your specific requirements. As a longtime provider of separation solutions to the largest producers of PVC, PC, HDPE, BPA, Melamin, PET, PMMA, ABS, and more, we have the knowledge and equipment it takes to ensure non-stop, reliable performance for any type of application.

SPECIFIC REQUIREMENTS? – UNDERSTOOD!

We begin with your needs and help you select the optimum solution from our broad range of separation technologies and services, including vacuum and pressurized drum filters, filter and belt presses, decanter centrifuges, filtering centrifuges (pusher, peeler), separators, drying/cooling systems, and more. And ANDRITZ also has the capability to offer mechanical separation and drying as one package. To date, petrochemical and polymer producers have installed more than 1,000 of our machines and many of them are still running 24/7 after over 40 years in operation.

For a tailored approach, our separation specialists can further refine and test your solution on-site or in our own state-of-the-art test centers. This means we can recommend and optimize the right solution for each process step – from solvent recovery to solidification, cooling, and more – to reduce costs, improve efficiency, and ensure continuous performance for the lifetime of every investment.

SUPERIOR SERVICE AND AUTOMATION? – ASK YOUR SEPARATION SPECIALIST!

Thanks to the global network of 550 service specialists for solid/liquid separation equipment and systems as well as service centers all around the world, ANDRITZ is on hand to ensure its customers' investments always deliver the maximum value. Our separation specialists also maintain close collaboration with customers in the field to continuously optimize moisture content, particle size, and mechanical reliability. Our on-site experience gives you a complete life cycle of reliable results. In addition to readily available OEM parts, process optimizations, testing capabilities, and much more, ANDRITZ also offers a wide range of automation tools. When it comes to automation and process control, the Metris addIQ control systems combine all of ANDRITZ's extensive operation, troubleshooting, and start-up experience in one tailored solution. With the broad portfolio of scalable automation solutions, applicable over a wide range of tasks including predictive maintenance, process monitoring, troubleshooting, and long-term trending, ANDRITZ can help to profit from the opportunities that come with digitalization: risk minimization, efficiency increase, and profit maximization – all from a single source.

www.andritz.com/separation

Economic Indicators

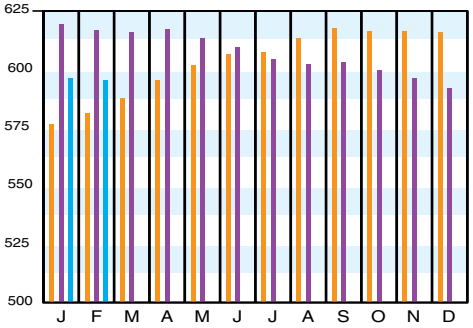
2018 2019 2020

Download the CEPCI two weeks sooner at www.chemengonline.com/pci

CHEMICAL ENGINEERING PLANT COST INDEX (CEPCI)

(1957–59 = 100)	Feb. '20 Prelim.	Jan. '20 Final	Feb. '19 Final
CE Index	595.4	596.2	617.1
Equipment	722.0	724.1	754.7
Heat exchangers & tanks	615.6	618.8	674.7
Process machinery	722.3	721.7	728.6
Pipe, valves & fittings	952.0	957.3	971.7
Process instruments	417.0	419.1	418.8
Pumps & compressors	1083.6	1080.2	1063.8
Electrical equipment	563.7	563.8	554.4
Structural supports & misc.	767.2	767.1	838.4
Construction labor	336.0	333.9	333.7
Buildings	590.8	588.2	599.7
Engineering & supervision	313.7	313.7	316.8

Annual Index:
2012 = 584.6
2013 = 567.3
2014 = 576.1
2015 = 556.8
2016 = 541.7
2017 = 567.5
2018 = 603.1
2019 = 607.5

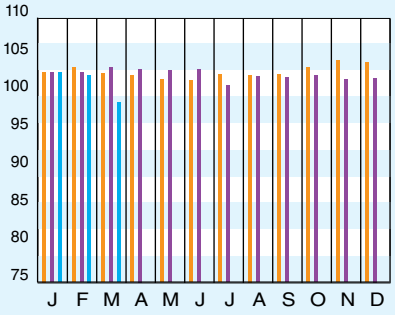


Starting in April 2007, several data series for labor and compressors were converted to accommodate series IDs discontinued by the U.S. Bureau of Labor Statistics (BLS). Starting in March 2018, the data series for chemical industry special machinery was replaced because the series was discontinued by BLS (see *Chem. Eng.*, April 2018, p. 76–77.)

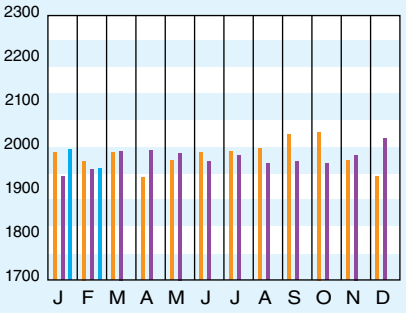
CURRENT BUSINESS INDICATORS

	LATEST	PREVIOUS	YEAR AGO
CPI output index (2012 = 100)	Mar. '20 = 98.8	Feb. '20 = 102.4	Jan. '20 = 103.3	Mar. '19 = 102.7
CPI value of output, $ billions	Feb. '20 = 1,953.4	Jan. '20 = 1,987.6	Dec. '19 = 2,022.0	Feb. '19 = 1,953.0
CPI operating rate, %	Mar. '20 = 73.4	Feb. '20 = 76.0	Jan. '20 = 76.7	Mar. '19 = 77.0
Producer prices, industrial chemicals (1982 = 100)	Mar. '20 = 238.3	Feb. '20 = 241.9	Jan. '20 = 245.8	Mar. '19 = 258.3
Industrial Production in Manufacturing (2012 =100)*	Mar. '20 = 98.3	Feb. '20 = 104.9	Jan. '20 = 104.9	Mar. '19 = 105.2
Hourly earnings index, chemical & allied products (1992 = 100)	Mar. '20 = 188.7	Feb. '20 = 185.9	Jan. '20 = 188.2	Mar. '19 = 184.1
Productivity index, chemicals & allied products (1992 = 100)	Mar. '20 = 100.1	Feb. '20 = 100.1	Jan. '20 = 99.5	Mar. '19 = 96.5

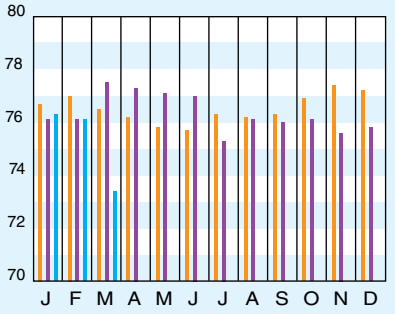
CPI OUTPUT INDEX (2000 = 100)†



CPI OUTPUT VALUE ($ BILLIONS)



CPI OPERATING RATE (%)



*Due to discontinuance, the Index of Industrial Activity has been replaced by the Industrial Production in Manufacturing index from the U.S. Federal Reserve Board.
†For the current month's CPI output index values, the base year was changed from 2000 to 2012
Current business indicators provided by Global Insight, Inc., Lexington, Mass.

CURRENT TRENDS

The preliminary value for the *CE* Plant Cost Index (CEPCI; top) for February 2020 (the most recent available) decreased slightly from the previous month's value, with the values of the four major subindices comprising the CEPCI being mixed. While the Equipment subindex was down for February, the Construction Labor and Buildings subindices were ticked upward. The Engineering & Supervision remained flat. The current CEPCI value is 3.5% lower than the corresponding value from a year ago at the same time. Meanwhile, the Current Business Indicators (CBI; middle) saw a drop in the CPI Output Index and CPI Operating Rate for March 2020, and decrease in the CPI value of output for February.